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CONTENTS.

FIRST PART—OCTOBER 1880. PAGE

SECOND PART—JANUARY 1881.

THIRD PART—APRIL 1881.

FOURTH PART—JULY 1881.

Journal of Anatomy and Physiology.

AN INFECTIVE FORM OF TUBERCULOSIS IN MAN IDENTICAL WITH BOVINE TUBERCULOSIS. By C. Creighton, M.D., *Demonstrator of Anatomy in the University of Cambridge.* (Plates I.–VI.)

I.—Definition of the Subject.

The occurrence of anomalous or unaccountable cases of general tuberculosis would appear, from the published records, to be by no means uncommon. But the pathology of tuberculosis in man has in the past been surrounded by so many difficulties, the interpretation of the morbid appearances and of their relation to each other, has depended so much upon an ever-shifting theory of the disease, that even the most unaccountable and mysterious cases have been regarded as only a degree more puzzling than the general run of tuberculous cases, and have been lightly consigned to that limbo of unexplained or half-explained cases which occupies so large a part of every *post-mortem* register. The group of cases that form the subject of this paper are probably not different from many that have occurred before. If they shall have escaped the fate of being thrown into the general unassorted heap of tuberculous cases, it is because they occurred in rapid succession, presenting day after day the same associated appearances, and thus arresting the attention and provoking curiosity to a degree that isolated cases, occurring at wide intervals of time, would probably have failed to do.

On the 17th April 1880, the *post-mortem* examination at Addenbrooke's Hospital was on the body of a man, aged twenty-one, who had been admitted with pulmonary symptoms, and had

died suddenly after being thirty-six hours in the hospital. The lungs contained a number of soft whitish masses, up to the size of a walnut, softened in the centre, most of them round, and one or two, on the periphery, wedge-shaped. The question was whether they were not secondary tumours; but they differed from the sarcomatous or other new growths that occur secondarily in the lung, and they differed still more markedly from cheesy deposits. Four days later there was a *post-mortem* examination on the body of a woman, aged thirty-eight, who had been in the hospital six months before with typhoid fever, and had been readmitted with obscure abdominal symptoms. Acute tuberculosis had been diagnosed, and we found both lungs full of very minute translucent tubercles, and one lung contained a single large sharply-defined wedge-shaped infarction on the periphery. This infarction recalled the wedge-shaped masses of the former case, but it differed from them in being firm and tough, and of a brownish-yellow colour, like a gumma. There were two small healed ulcers in the ileum, and the peritoneum generally was covered by an eruption of large flat tubercles. About a week afterwards (28th April), there was a *post-mortem* examination of the body of a girl aged seventeen. The under surface of the diaphragm and other parts of the peritoneum were covered with the same large flat tubercles as in the preceding case, and one lung contained precisely the same white medullary tumour-like masses as in the first case. One of the white masses (figured at the top of Plate III.) was distinctly wedge-shaped. A few days later (4th May) the body of a child, aged eight, was examined. The case had been a typical one of acute tuberculosis, of about five weeks' duration. The tubercles in the lungs were large and white, and at one apex they were so close together as to form on the periphery of the lung a solid wedge-shaped mass an inch long. Lastly, on the 14th May, an examination was made of the body of a man, aged 42, who had died of acute pulmonary disease after being four days in the hospital. The appearance of the left lung was remarkable; it was intensely œdematous; it presented a number of large cavities, more or less smooth in the interior, and containing putrid-looking greyish fluid; one or two of the cavities in the periphery of the lung were wedge-shaped, and the lung tissue

between the cavities was everywhere occupied by round nodules as large as peas, of a uniform size, and of a dirty grey colour.

I had in the meantime been examining carefully all the material that I had collected from the cases as they occurred, and, after a time, it occurred to me, from certain points of likeness in the morbid products, that we had here to deal with bovine tuberculosis communicated to man. Certain of the morbid appearances led me to go back upon three equally unaccountable cases of tuberculosis in adults that had died in the hospital in February and March, and from which I had preserved portions of the affected organs. I did not hesitate to include those three cases along with the others as cases of distinctive and specific bovine tuberculosis. Having examined the whole of this material, and having been kindly permitted by Dr Latham and by Dr Bradbury, in whose respective services at the hospital the patients had been, to make use of the cases, I communicated my observations to the Cambridge Medical Society on 4th June, and the communication was published in the *Lancet* of 19th June 1880. After recording the cases, I continued:—

"My contention is that these cases of tuberculosis are all of them cases of bovine tuberculosis; that they show the distinctive and specific characters of that disease in their pathological anatomy and are related to it in their etiology, and that they have precisely that relation to bovine tuberculosis which glanders in the human subject has to equine glanders. Bovine tuberculosis (*Perlsucht*, *Pommelière*) is a disease by itself, as much as glanders is. It is only from directing too concentrated an attention upon its histology that one would be led to conclude, with Schüppel,[1] that bovine tuberculosis is identical with the ordinary indigenous or autochthonous tuberculosis of man. It has well-marked distinctive characters,[2] which appear to me to be reproduced more or less in all the cases above related. I must content myself for the present with summarising in the briefest way what may be considered to be the salient features of the cases that I have grouped together, without attempting to make out the identity with bovine tuberculosis from point to point."

The summary related chiefly to distinctive appearances, microscopic and other, in the lungs, in the lymphatic glands, and on the serous membranes.

Since the first series of eight cases were published, four more

[1] Virchow's *Archiv*, vol. lvi. (1872), p. 38.

[2] See Virchow's *Lectures on Tumours* (French translation), vol. iii. p. 184.

cases of precisely the same nature have occurred at Addenbrooke's Hospital, and these I include in the present paper by permission of Dr Bradbury. They were examined *post-mortem* on 26th June and 1st July, and on 2d and 4th September. The case on 1st July has afforded me the best specimens that I possess of the characteristic pleural outgrowths (figured in Plate I.), and those on the 2d and 4th September have afforded good examples of the intestinal lesion. These additions bring up the number to twelve. I have omitted three cases that occurred within the same period of seven months, as being somewhat ambiguous.

In attempting to detach any particular group of tuberculous cases from the great unassorted congeries of such cases, one is met by difficulties of no ordinary kind. The characters exemplified by the present series of twelve cases, characters which I shall maintain in the sequel to be distinctive of the specific tuberculosis of bovine animals, have doubtless all of them been already noted and included, in one place or another, among the manifold characters of tubercle. There is probably nothing in the coloured plates which those who frequent the dead-house are not more or less familiar with; while, as regards the microscopic drawings, the definition of tubercle as given by Rindfleisch[1] and by Schüppel[2] would cover nearly all that they show.

By what means, then, do I hope to isolate this particular group of cases, and to determine for them such specific characters as would satisfy the classification test of a systematic zoologist or a systematic botanist? It is not by tracing the individual cases to particular sources of poisoning or of infection, nor is it by the test of experimentally inducing the disease by the inoculation of the substance in animals. I rely solely upon the specific and distinctive characters of the tuberculosis that affects the bovine species, and on the morphological identity that I shall prove between that kind of tuberculosis and the disease that occurred in the group of twelve cases in man. The bovine disease, in being communitated to man, may be somewhat modified; just as glanders in man is not precisely the same

[1] Rindfleisch in Ziemssen's *Handbuch*, vol. v. 2, p. 162, fig. 1.

[2] Schüppel, *Untersuchungen über Lymphdrüsen-Tuberkulose*, Tübingen, 1871.

as equine glanders. The specific tuberculous disease of the cow or ox is a very slow disease, which may escape notice for years and not seriously interfere with nutrition, and it is either of spontaneous origin or probably (in most cases) inherited; the corresponding disease in man is of the nature of a more or less acute infective disease, with the clinical symptoms of an infection predominating. But so remarkable is *the structural mimicry that resides in infection*, that the disease communicated to man reproduces the special anatomical characters of the bovine disease with a surprising degree of accuracy. The older German veterinary surgeons designated bovine tuberculosis as *Meerlinsigkeit* or "Duckweed," from the curious resemblance that the outgrowths on the serous membranes have to the dense masses of small round or oval leaves that float on the surface of a pool, presenting a somewhat convex surface, and imparting the notion of solidity. The coloured plates of the disease in man show several instances of this or the allied appearances, and the upper figure in Plate I., showing the pleural surface of the concave base of the lung, from one of the latest cases, will probably serve to suggest "duckweed." The later and more usual German name for the bovine disease is *Perlsucht*, or "pearl disease," the French name is *Pommelière*, or "potato disease," the name in Scotland is *Angle-berries*, and the most usual colloquial English name is *Grapes*. All these names are popular designations; they all relate to the same somewhat superficial condition, or different degrees of the same condition, viz., the formations on the serous membranes; they involve no theory of the disease; but they are as if the outcome of the everyday observation of those who have to do with cattle in various European countries. "Duckweed," "pearls," "potatoes," "angle-berries," and "grapes" present certain differences among themselves, but it is admitted on all hands that the disease of which they are the colloquial names is always one and the same. It is a specific disease, and *it is primarily a disease of the ox and cow.* It is to the bovine species what glanders is to the equine, and what syphilis is (perhaps) to the human species. If we look at bovine tuberculosis in the light of any one of its various colloquial names, we cannot but admit that it possesses specific characters, which would satisfy the classification test of a

systematic naturalist, and which are, as far as they go, sufficiently fixed and determinate for an argument of morphological identity in the human subject to be based upon them.

If the bovine disease had been limited in its manifestations to the serous outgrowths from which its names are taken, no one would ever have said that it was the same as human tuberculosis. It always affects the lungs as well, and an almost equally constant character is the implication of the lymphatic glands. I hope to show in the next section that the affections of the lungs and lymphatic glands are themselves special and distinctive of the disease in bovine animals, equally with the serous-membrane outgrowths. If the naked-eye characters alone are relied on, there need be no question of the distinctiveness of the morbid condition, whether in the lungs and lymphatic glands, or on the serous membranes. It is only when the microscope is applied, that the disease is resolved into the same fundamental textural processes as we suppose to be characteristic of tuberculosis in man. That is the contention of Schüppel (*loc. cit.*); I shall have to examine the argument of that author at some length in subsequent sections of this paper.

In the meantime, an obvious objection may be taken to the histological argument of Schüppel, that bovine tuberculosis and human tuberculosis are identical, and to the corresponding arguments from experiments put forward by Chauveau, Villemin, and Klebs. The two terms of the comparison, or the two sides of the identity, do not stand on the same footing. The disease in the cow and ox is a specific disease, about the distinctive characters of which there is no difference of opinion. Treatises on veterinary pathology enumerate certain morbid conditions in the lungs from which it is to be distinguished; but the diseases most likely to be mistaken for it are hydatids in the cow, lymphoma (chiefly of the horse and dog), and strongylus in sheep. It does not appear that it can be readily confused with pleuro-pneumonia, and, within the bovine species itself, its *post-mortem* diagnosis may be said to be singularly free from difficulty. But can the same be said of "tuberculosis" in man? What are called tubercular diseases in man are a congeries of morbid conditions which half-a-century of sifting and sorting has not served to reduce to order. That this ill-assorted congeries of cases, this dust-bin of pathology

should contain some (if not a large proportion of) cases of the specific bovine disease is conceivable. But the one known quantity in this problem is the specificity of the bovine disease, and it is only such cases in the human subject as have the specific marks of bovine tuberculosis that can be said to be identical with it. If, on the other hand, any given case or cases of tuberculosis in man are taken as the starting-point of a comparison, and the same characters are found to obtain in the tuberculosis of the cow and ox, that only proves that the particular human cases *are* cases of the specific bovine disease. It would simplify greatly the problem of human tuberculosis if all cases of the disease in man presented the bovine characters. There would be no question at all as to the origin of the human disease, as to where it had come from. But there is naturally no such simplicity for tuberculosis in man. A class of cases, which I have referred to above as autochthonous or indigenous cases of tuberculosis, doubtless exists; they are said to be due to the self-infection of the organism from a primary focus of suppuration or caseation, and in favour of that hypothesis there is the strict analogy of metastatic tumours and of metastatic abscesses. After that somewhat restricted class of cases, we come at once to the residue which pathologists find it so difficult to assort. I maintain that the unassorted residue contains some (if not many) cases of the specific bovine disease communicated to man. But the only way to track such cases is to take one's departure from the clearly-marked specific characters of the bovine disease, and to search closely among the human cases for such as have an exact and complete identity of morphological characters. It is only to the most unbounded faith in the *structural mimicry of infection* that success in this quest will be given. Whoever has followed closely the infective process in tumours, and has observed in the secondary nodules the marvellous mimicry of the complex structural details of the primary, will not find it hard to believe that the singular appearance on the pleura in Plate I. is due to infection from a case of that disease to which the name of *Meerlinsigkeit* or "Duckweed" is sometimes given. The conviction that such cases are of bovine origin is greatly strengthened by the discovery that the lungs and lymphatic glands reproduce the condition of the corresponding organs in the cow in a no less accurate copy.

In trusting so much to a morphological test of identity, I may appear to some to be resting my whole case upon an obsolete and discarded method of procedure. The utterances of Professor Cohnheim on this matter are certainly disquieting.[1] "To tuberculosis," he observes, "belongs all that can, by its inoculation on suitable experiment-animals, produce tubercle, and nothing is tuberculous which produces no effect after inoculation. How much is gained by this definition, those only can sufficiently appreciate who have seriously taken pains to study the anatomical history of chronic pulmonary tuberculosis in the body of the ordinary consumptive. Let one endeavour as much as he will, it is of no avail; the anatomical definition is of no use any longer for tubercle, but it must yield to the ætiological. To those who deplore this—and I do not ignore the fact that a certain amount of inconvenience has thereby arisen for *post-mortem* diagnosis—I would say that they should not give up hope of even the anatomical definition again coming to its rights. That the problem of assigning morphological characters *to the tuberculous virus* is already solved, I would not venture to say, even after the latest labours of Klebs, distinguished as these are by care and diligence. But, whoever is convinced of the parasitic nature of the infective kinds of virus, will not hesitate to believe in the corpuscular nature of the tuberculous poison also, and will so remain in confident expectation that, in a not too distant future, proof will be furnished of the existence in the interior of tubercle-nodules and scrofulous products, of specific corpuscular elements which those who are fond of historical names may again designate as 'tubercle-corpuscles.' So long, however, as this end is not reached, there is no other sure criterion for tuberculosis than its infectiveness."

The minute organism, when found, will probably turn out to have a close family likeness to some other minute organisms, and its value as a morphological test may not be so great as its friends and admirers expect. But as regards our existing means of anatomical or morphological definition, it is hard to agree with Professor Cohnheim that they are so hopelessly bad as he makes them out to be. The picture presented by "chronic pulmonary tuberculosis in the body of the ordinary consumptive" is no

[1] Cohnheim, *Die Tuberculose vom Standpunkte der Infectionslehre*, pp. 13, 17, 18. Leipzig, 1880.

doubt varied enough to drive even experienced observers to distraction. In like manner, the microscopic definition of tubercle as a lymphoid growth, or as a growth of lymphoid tissue and giant-cells, or as a nodule with a giant-cell in the centre and epithelial cells in the next zone, and lymphoid cells round the edge, is not a good working definition suitable for all cases. But we should be throwing away a useful weapon, if we abandoned the morphological or anatomical test altogether. According to Professor Cohnheim, all tubercle is due to infection from without; but though Professor Cohnheim generalises infection to the utmost extent and looks forward to the day when the "tubercle-corpuscle" shall have been discovered in the form of a minute organism, he does not assert that the tubercle-infection is always one and the same infection. Tuberculosis, according to him, is for the most part transmitted by infection from individual to individual within the human species, the infecting germs being for the most part introduced with the inspired air; but he allows a place to the conjecture, often repeated since Gerlach first made it in 1869, that the milk of tuberculous cows may also be an agent of infection, and is specially to be held accountable for the tuberculosis of children. Like most of those who touch on this subject, he readily assumes that the tubercle of man and the tubercle of the cow are one and the same thing; the only question is whether it is "tubercle," and the answer is found in testing its communicability by experiment. I say that this modern method of treating the question is to make an unjustifiable surrender of valuable morphological details. The tuberculosis of the ox and cow has well-marked distinctive characters; infection carries with it a remarkable degree of structural mimicry; and if human beings are infected with the tuberculosis of the bovine species, the new formations in their bodies will be like the new formations in the bodies of bovine animals. To establish the proof of a communication of the bovine disease to man, I rely upon identities of structure, and upon these alone. The experimental test is obviously out of the question, and the micro-organism test is not yet ripe for general use. The only alternatives are, either to make conjectures and start convenient hypotheses in the prevailing manner of Professor Cohnheim's suggestive essay, and so to fail in making any headway with one's ideas in the estimation of practical men, or to put

together as carefully and exhaustively as possible, all the evidence of identity in structure between the disease in the bovine species and the suspected cases in man. Whoever believes in the marvellous mimicry of infection will not be afraid to look for, and will not be astonished to find in the infected human body a wide-spread and varied condition, which reproduces, in the respective localities and as a whole, the condition in the bovine animal out of which the infection has proceeded. It is chiefly in the serous membranes, in the lungs, and in the lymphatic glands that the typical lesions are found both in the infecting and in the infected organism.

I have thus sought to define the scope of my inquiry. It purports to trace the tuberculosis of twelve cases in man to infection or poisoning from the cow or ox, and the evidence relied on is the identity of the diseased product. Professor Virchow, who lays much stress on the specific and distinctive characters of bovine tuberculosis (*Perlsucht*), said, in an address to the Berlin Medical Society on 10th March 1880, "We must in any case bear in mind that no man has ever yet acquired pearl nodules through partaking of tuberculous (*perlsüchtig*) flesh."[1] I maintain that the twelve cases recorded in the sequel show precisely those specific characters of which the "pearl nodules" are the most familiar example. These cases are, so far as I know, the only cases hitherto published which formally claim to be cases of the specific bovine tuberculosis communicated to man.

II.—Summary of the Pathological Anatomy of Tuberculosis in the Bovine Species.

Bovine tuberculosis is a widely-spread disease among cows and oxen; accurate statistics are not generally procurable, and the estimates of its frequency vary within wide limits. One of the most precise statements that I have met with is that relating to the town of Augsburg;[2] 2·16 per cent. of all the oxen and cows slaughtered in the course of the year 1877 were affected with the disease, and among cows alone the percentage was 4·75. The larger number of animals affected were over six years of age, which accounts for the higher percentage in cows.

[1] Virchow, *Berliner Klin. Wochensch.* No. 14 (5th April) 1880.
[2] Adam, reported in the *Jahresbericht* for 1878, p. 611.

According to other statements, the slighter indications of the disease, such as the growths on the serous membranes (which, according to Williams,[1] have no great pathological significance, being "external to the general economy of the animal"), are much more common. Bad cases of the disease are sometimes condemned by the inspectors, but the disease is not scheduled in any of the acts relating to the diseases of animals, and inspectors appear to have insufficient powers to deal with it. It is a matter of much greater practical importance that the use of the milk of tuberculous cows is entirely uncontrolled.

The disease is generally admitted to be hereditary, and the intensity of its course to depend on bad hygienic conditions. Its progress is usually very slow, and it may exist for years unsuspected. It ultimately declares itself by wasting and cough, and by certain physical signs. Cows in an advanced state of tuberculosis give a diminished quantity of milk, and the milk is thin and of a bluish colour.

The parts chiefly affected are the serous membranes, the lungs, and the lymphatic glands.

1. *The condition of the Serous Membranes.*—It is from the morbid appearances on the serous membranes that all the colloquial names of the disease are derived. Thus, it has been called *serous tuberculosis*, *Meerlinsigkeit* ("duckweed"), *Perlsucht* ("pearl disease"), *Pommelière* ("potato disease"), "angle berries," "grapes." The name of "duckweed" relates to the small round outgrowths on the pleura and peritoneum, sometimes thin and membranous, but also nodular or solid, like the duckweed leaf itself. *Perlsucht* relates to the same round or flat nodules on the serous membranes, but includes the more pendulous variety, like strings of pearls. The remaining names of *Pommelière*, "angle-berries," and "grapes," relate to a still further development of the same kind of serous outgrowths; the smaller size is the most common (miliary or lentil-sized nodules), but the larger nodules, being more striking, have in some countries given the name to the disease. The following account of the development of the serous-membrane eruption is given by Walley[2]:—"The early stages in the

[1] Williams, *Veterinary Medicine*, p. 346.

[2] Walley, *The Four Bovine Scourges*, p. 169, Edinburgh, 1879.

process are diffuse and intense capillary congestion, followed rapidly by the formation of innumerable villous-like vascular processes, very minute, and giving the membrane an appearance closely resembling the pile on red velvet. In the course of time the extreme vascularity of these little processes passes off; they assume a definite shape, and become converted into small hard globular nodules, of the colour of connective tissue. Gradually, however, they become grey, and somewhat translucent on section, and constitute the so-called grey or fibrous tubercle. These grey miliary nodules may remain discrete, and scattered over the surface of the membrane, like millet seeds; or they may become connected together by delicate bands of new connective fibrous tissue. When tuberculisation is very rapid, distinct polypoid processes, as seen in fig. 7, Plate X., may be formed on the membranes. These bodies are often at the outset very vascular, in fact, hæmorrhagic." Besides the illustration referred to in the quotation, a good picture of the large form of polypoid outgrowths on the pleura will be found in Carswell's plate of the lung of a tuberculous cow.[1] A critical analysis of the bovine disease is given by Virchow in his great work on Tumours (vol. iii.). With reference to the serous-membrane outgrowths, he observes—"Whatever analogy this development may present in general with the tuberculosis of man, the size and the pedunculated disposition of the nodules always afford a striking means of distinguishing it."

2. *The condition of the Lungs.*—The morbid anatomy of bovine tuberculosis has been carefnlly studied by M. Trasbot, Chef de Clinique at the Veterinary School of Alfort. The following is Trasbot's account of the pulmonary lesion:[2]—"The tubercles in the lungs are essentially all of small size, from a point scarcely visible to a millet or hemp seed. The larger masses are formed by the confluence of a number of the small tubercles. The colour is at first greyish-white, and semitransparent, but when the development is complete, it is somewhat

[1] Carswell, *Pathological Anatomy*, fig. 4, Plate I. (Tubercle), London, 1838.

[2] I take this account from Fleming's *Manual of Sanitary Science and Police*, 2 vols. 1875, vol. ii. 376. It is there compiled from Reynal's *Traité de la Police Sanitaire*, Paris, 1873. I have learned on inquiry that M. Trasbot's observations are contained in several papers in veterinary journals, to which I am, unfortunately, not able to refer.

yellow and opaque. A tubercle is found to be developed along a small artery, most frequently at the angle formed by a terminal division of the vessel; sometimes around a capillary, on which it forms a kind of bead, or in the network of an anastomosis which envelops it on every side. When the tubercle is fully developed, it contains no vessel in its interior. *Vessels are more numerous in the tissue around the nodules, and in the septa or interstices of the large masses of tubercle, than in the healthy connective tissue; there the vascularity is oftentimes so great as to be mistaken for inflammation.*

"This absence of vessels in the tissue of tubercles serves to explain why, *nourished exclusively at their periphery*, they have only acquired small dimensions before the central necrobiosis commences; and this special peculiarity distinguishes them from sarcomatous tumours, with which Virchow has unrestrictedly assimilated them. The tubercles so developed undergo successive modifications, which so alter their character that many observers have denied their identity. The two chief modifications are calcification and softening.

"*a. Calcification.*—The centre becomes calcified, while the periphery remains fibrous, *and simulates a capsule.*

"*b. Softening.*—This alteration commences at the centre, and extends towards the circumference of the tubercle, until there remains nothing but the surrounding connective tissue; and its appearance would lead superficial examiners to think that it was encysted, as it forms a badly-defined cavity, the contents of which are easily detached. Sometimes several contiguous tubercles break up simultaneously, and the septa between them disappear, leaving cavities sometimes larger than a walnut. These vomicæ are of various shapes and dimensions, and *are often confounded with other cavities which are formed in a very different manner.* The vomicæ have no proper walls, but are merely surrounded by the more or less indurated connective tissue that constitutes the stroma of the tubercular masses, and their interior is not vascular like that of cavities resulting from inflammation. These vomicæ are closed, and have no communication with the bronchi or pleural sacs. There is no natural demarcation between them and their contents, as in cysts and abscesses, the gradation being insensible. The central

mass is more or less coherent, according to the degree of softening at which it has arrived; it is white and plaster-like if calcification has already occurred, and it has a greyish-yellow colour and cheesy consistency in the contrary case."

To this account of Trasbot, which I regard as of the highest importance for the proof of identity which I shall set up for the lung lesions, I shall add an extract from the work of Walley:—"The degenerative processes are principally softening, which commences centrally, and cretification, though the latter may succeed the former if it is not very rapid in its progress; usually, as the nodule softens, the amount of surrounding tissue condenses, constituting a veritable capsule (the old so-called encysted tubercle), which in rapid softening becomes extremely hyperæmic." Under the head "Lung," he writes:—"As the softening process goes on, the tuberculous deposits become surrounded by a tolerably thick insulating wall or envelope of condensed and new connective tissue; and, as in encysted pleuro-pneumonia lung, the inner surface of this boundary wall frequently becomes very active—granulations forming and interpenetrating the tuberculous mass. In some instances, these softened masses coalesce, and, if the boundary wall preserves its integrity, form large tubercular abscesses, the contents of which, owing to the absorption of the fluid, may again become dry and caseous; but if the cyst wall becomes the seat of ulceration (a comparatively common occurrence), a communication is formed with the nearest bronchial tube, and the contents evacuated into it. In these cases, the boundary wall is frequently very hyperæmic, with numerous small yellow nodules adhering to its internal surface, and with evidence of recent hæmorrhage. I have in my possession a specimen of concurrent hydatid disease and tubercle, in which a communication exists—by ulceration between the hydatid cyst and the tuberculous cavity" (p. 186).

Fleming divides the pulmonary lesions into essential and accessory or contingent. The essential are—tubercles, and closed vomicæ resulting from the central softening of these. The accessory are—acute or chronic inflammation of the pleuræ, bronchitis, with cavernous dilatations, &c. It is to be observed, that while he includes cavernous dilatations of

the bronchi among the accessory conditions, he places among the essential "closed vomicæ resulting from the central softening of tubercles." Fleming states that the tubercular matter in the lungs appears to be first deposited in the cortical or peripheral portion, and always in the subpleural and interlobular connective tissue.

From the above extracts, it may be concluded that the tubercles in the lungs have a vascular periphery simulating a capsule, and a non-vascular centre. The centre becomes calcified or softened, and the periphery remains as the vascular capsule of a calcareous nodule, or as the wall of a vomica. Several small single tubercles, forming a larger tubercular nodule, undergo the degeneration together, and the excavated centres of several nodules may communicate and form a large and irregularly-shaped vomica. The careful observations of Trasbot appear to have established that process as characteristic of the pulmonary lesion in bovine tuberculosis. Strange to say, this rational and in every way credible account of the condition of the lungs, given by competent veterinary pathologists, has either been overlooked or it is disputed by writers on human pathology who have approached this subject. Thus, Schüppel, writing on the identity of tuberculosis with *Perlsucht*,[1] and naturally seeking to have the two sides of his proposed identity each clearly defined, was disconcerted at the outset by "the variety of processes that occurred side by side" in the lung of the tuberculous cow from which he derived his material. "Apart," he says, "from the large and somewhat numerous cavities filled with inspissated pus (bronchiectasies), I found only about one-twentieth or one-thirtieth of the lung lobules to be diseased." He distinguished in the lung two kinds of morbid product—first, the inflammatory infiltration; and, second, the nodules. The latter were grey, fairly translucent, projecting nodules of miliary or sub-miliary size, partly separate and partly confluent. These alone, he admitted, to belong essentially to the tuberculous condition, and the "identity between tuberculosis and *Perlsucht*" rested, as regards the lung, on the exceedingly narrow basis of certain points of agreement in the ultimate analysis of the structure with the microscope.

[1] Virchow's *Archiv*, vol. lvi. (1872), p. 38.

The fallacy that all smooth-walled vomicæ in the lung are nothing but portions of dilated bronchi—a fallacy of comparatively recent origin, and mostly prevalent in Germany—had doubtless led Schüppel to set aside, as an accessory of the disease, one of the most constant and characteristic indications of bovine tuberculosis in the lung. I cannot but think that a similar laxity of opinion on the subject of smooth-walled vomicæ is to be held accountable for the following opinions of Virchow. On the 10th of March 1880, Professor Virchow gave, before the Medical Society of Berlin, an account of the present state of the question relating to the experimental communication of bovine tuberculosis to other animals, with special reference to a series of experiments that had been going on for several years under his own direction.[1] I shall refer, in the next section, to the general evidence on that subject. After four years experimentation under Virchow's direction, a decided conclusion had not been reached, owing to the great difficulties, demanding an almost portentous amount of caution, that beset the experimenters on every hand. The difficulties were of two kinds, theoretical and practical. Among the theoretical difficulties was that which had formerly disconcerted Schüppel, viz., the variety of conditions that occurred side by side in the tuberculous lung. "As in the human lung," says Virchow, "so also in that of the cow, certain chronic inflammatory diseases, which might easily be taken for tuberculosis, are remarkably frequent. Since I have studied this subject more closely, I have myself been surprised at their frequency. But I have been equally surprised at the want of information concerning them in the writers of the profession. Quite especially frequent in cattle are forms of bronchitis, with retention of the contents, and every possible kind of bronchiectasis. They are so frequent that they must be considered to be, even as contrasted with what we find in man, a very usual occurrence. These forms of bronchitis and bronchiectasis nearly all have the peculiarity that the secretions remain in the canals, accumulate more and more, gradually become inspissated, and finally assume a compact, dry, caseous consistency, and not seldom even pass into petrifaction, as indeed

[1] Virchow, "Ueber die Perlsucht der Hausthiere, und deren Uebertragung durch die Nahrung," *Berliner Klin. Wochensch.* Nos. 14 and 15 (5th and 12th April) 1880.

happens in man in a similar way. If, now, a great part of the lung has become changed in this wise, if there is found at various places a series of irregularly dilated bronchi with saccular or bead-like recesses, so it easily comes to pass, on section of the lung, that one finds a number of hard fibrous nodules with calcareous deposits. Indeed, there is no mistaking the fact that this picture may in a high degree come to resemble that which is furnished by cross section of those tuberous masses which represent the peculiar and characteristic elements of *Perlsucht.* I must state with emphasis that in many cases the most extensive bronchitic and bronchiectatic changes, with accumulation of whole masses of caseous substance, may occur in cattle, without a single trace of *Perlsucht* being present. Those who call all these things tubercle, because something caseous or calcareous is contained therein, have certainly a wide field before them. I have by chance within the last day or two, when engaged in procuring some fresh material for demonstration this evening, met with the lung of an ox in which, besides pearl-nodules on the surface, a wide-spread condition of bronchiectasis was to be seen." When Virchow, in the above passage, expresses surprise that veterinary writers have not discussed that remarkable condition of lung which he so graphically describes, I cannot but think that the writings of Trasbot have remained unknown to him. It is precisely to that condition of lung that Trasbot's minute investigations have been directed; he gives a rational and credible account of the origin of the smooth-walled cavities, and he expressly states: "These vomicæ are of various shapes and dimensions, and are often confounded with other cavities which are formed in a very different manner." Again Fleming writes: "These vomicæ [in the lungs], according to Trasbot, appear to be closed, and have no communication with the bronchi or pleural sacs." One recalls to mind how Virchow's penetrating analysis of the condition of the lung in the ordinary chronic phthisis of man, struck at Laennec's doctrine of the unity of phthisis, and resolved the disease, for the most part, into chronic inflammatory conditions of the tissues. The maxim "Distinguo" is one that is constantly called for in pathological anatomy, but I do not doubt that a still more rigorous application of that maxim would have prevented all those remarkable cavities or dilatations

in the bovine lung from being swept into the general class of bronchiectasis.

I have delayed over this part of the subject, because it has a most important bearing on the identification of bovine tuberculosis in man. In several of the cases in my series, the lungs presented the crumpet-like condition of numerous smooth-walled vomicæ; when the first case occurred, showing that condition of lung, I had not yet been led to think of bovine tuberculosis, and I then took it to be bronchiectasis. Not only so, but I communicated it to the Cambridge Medical Society on the 5th March, as a case of bronchiectasis combined with miliary tuberculosis. Another case, showing precisely the same condition of lung, occurred shortly after, and in going into the matter more minutely, and in conjunction with cases which were suggestive, in other ways, of the bovine disease, I could find no evidence of dilated bronchi, but, on the contrary, evidence of that softening process of tuberculous nodules which Trasbot describes for the bovine lung. I included that observation in my preliminary notice in the *Lancet*, at a time when I was unaware of the observation of Trasbot, or of the significance of this condition for the identity of the two diseases. The figure on the lower part of Plate III. represents the condition which I at first took for bronchiectasis.

3. *The condition of the Lymphatic Glands.*—The thoracic and abdominal glands are so often affected in bovine tuberculosis that one of the numerous names of the malady is "gland disease."[1] According to Spinola, the glands are affected in an inverse proportion to the affection of the serous membranes, and *vice versa*, an observation which Virchow sees no reason to controvert.[2] The affection of the serous membranes is supposed to be the first manifestation of the disease. It is chiefly the bronchial and mediastinal clusters of glands, and the mesenteric and retroperitoneal that are affected. They sometimes grow to an enormous size. They are liable to the same degenerations as the morbid products elsewhere, and especially to cretaceous deposits.

In the section of an enlarged gland, numerous separate round nodules are found; externally also the individual glands have

[1] Virchow, *Tumours*, iii. 185 (French transl.)
[2] *Ibid.* p. 187.

sometimes a nodular appearance from the growth of several independent centres within them. Schüppel found that the tubercles or nodules take origin at various centres in the follicular tissue, and that they do not arise either in the lymph-sinuses or in the substance of the trabeculæ. Like the tubercles in all other parts of the animal, those in the lymphatic glands contain numerous giant-cells. A somewhat remarkable statement is made by Trasbot, viz., that the tubercles do not form within the lymphatic gland, but in the connective tissue that unites the several glands in one cluster. I shall refer to that point in speaking of the condition of the lymphatic glands in the cases in man.

4. *Tuberculosis in other Organs.*—In the *liver*, according to Walley, "the tubercular masses vary materially in size, and are not encysted in the true sense of the word, though, if softening has been rapid, a distinct boundary wall of new connective tissue is formed, which is sometimes very vascular" (*loc. cit.* p. 174).

In the *intestine*, according to the same authority, ulcers sometimes occur. "The edges and base are thickened, and the former are in some instances intensely hyperæmic. Prior to the irruption of the ulcer, in chronic cases, the mucous membrane is elevated by the tuberculous nodule, which is readily distinguished by its yellow colour; after irruption, small masses of tubercle are seen adhering to the submucous tissue" (p. 175).

The disease also affects the *genito-urinary system.* It in some cases affects the *joints,* the lameness so produced being not unfrequently the first symptom to call attention to the existence of the disease in the animal.[1]

Lastly, in the *mammary gland,* according to Walley, "the tubercle is usually of the fibrous form. The nodules are very numerous, developed in the acini; but even when the gland has been extensively invaded, I have not been able to trace any tendency to cretification. The acini are hypertrophied, and the interglandular tissue increased, giving the gland, on section, a coarse rarified appearance. Some nodules may be developed in the mucous membrane of the ampullæ or the ducts, but I have neither seen softening nor ulceration. The gland in the areas of invasion is of a reddish hue, from increased vascularity.

"Involvement of this organ, especially if ulcers are developed

[1] Williams, *Veterinary Medicine,* p. 348.

on the mucous membrane, is a matter of great danger, inasmuch as the irritation of the tubercle gives rise for a time to increased functional activity of the gland, the secreted milk becoming contaminated with the tuberculous products, and propagating the disease to any animal (or man) which may be unfortunate enough to partake of it" (p. 172).

The condition of the udder in tuberculosis of the cow has been made the subject of a special investigation by Kolessnikow, at the instigation of Virchow. The tubercles were found to grow in the stroma of the gland, and to contain the same elements (including giant-cells) as elsewhere.[1]

III.—Communicability of Bovine Tuberculosis to Animals by Experiment.

The credit of reviving attention to the danger incurred by the human species from tuberculous cows and oxen, is assigned by Virchow to the late Herr Gerlach, Director of the Veterinary School of Hannover, and afterwards Director of the Veterinary School of Berlin. To test the communicability of bovine tuberculosis, Gerlach experimented largely with animals such as the rabbit, sheep, goat, calf, and pig, inoculating the nodules from the cow under the skin, or feeding the animals with the actual morbid products, or with the milk of the diseased animal. Numerous other experiments of the same nature have been made, some of them contemporary with, or nearly contemporary with those of Gerlach, and some of them more recent; an excellent account of most of these is incorporated in an article by Fleming, which deals mainly with the somewhat wider question raised by the historical discovery of Villemin.[2] I shall confine my summary entirely to the experiments of Gerlach, for the reason that Gerlach primarily occupied himself with the communicability of bovine tuberculosis as a specific disease, and that the record of his experiments makes note of and emphasises precisely those minute identities of structure in the infecting and in the infected animal, upon which the stress of my own argument for cases of the disease in man also falls. The observations

[1] Kolessnikow, Virchow's *Archiv*, vol. lxx. (1877) p. 531.

[2] Fleming, "The Transmissibility of Tuberculosis."—*British and Foreign Med. Chir. Review*, vol. liv. (1874) p. 461.

of Gerlach are those of an experienced veterinary pathologist, well acquainted with the disease as it exists primarily in the bovine species, and his statements as to the morphological identity of the communicated disease are of quite exceptional value.

The paper by Gerlach, from which I shall quote somewhat freely,[1] using *italics* where necessary, records two classes of experiments, the first being a series of eight inoculations under the skin of nodules from the cow, and the second a series of eight feeding experiments with the nodules or with the milk of the animal. I shall quote one of the former class, and three (wholly or partially) of such of the latter as refer to feeding with milk. Before doing so, I shall quote the facts relating to a tuberculous cow which furnished the material for several of the experiments.

A cow, seven to eight years old, was procured for the purpose of the experiments. The animal was wasted, had difficult breathing and cough Râles in the chest were audible, but there was no dulness. Fever had not yet set in, and the appetite was good. The daily yield of milk was 1500 grammes. Killed after three months; during that interval the wasting had increased, and the amount of milk had become less (during the first month the daily average was 600 grammes, during the second month 500 grammes, and during the last eight days it was almost absent, the animal being well fed all the time).

Post-mortem.—Parietal, diaphragmatic, and mediastinal pleura covered with innumerable smooth glancing nodules from size of lentil to that of pea; the pulmonary pleura more sparsely studded with nodules. There were present no conglomerates of nodules nor grape-like masses on the serous membranes. The lungs were voluminous and of double the usual weight. On handling them, they felt normally elastic in some parts, and in other parts firm and nodular. The bronchial glands were remarkably enlarged, hard and nodulated to the feel, and creaking under the knife. On the cut surface of the lung, a considerable amount of destructive change—small and large cavities, some with muco-purulent, others with caseous contents, *and with thick smooth walls;* also miliary tubercles from size of a mere visible point to that of millet seed, partly scattered and partly aggregated together.

Commenting afterwards on this case, he observes—"It is quite usual to find destructive changes in the lungs in *Perlsucht*, besides the nodules on the serous membranes. I have never

[1] A. C. Gerlach, "Ueber die Impfbarkeit der Tuberculose und der Perlsucht bei Thiere, sowie über die Uebertragbarkeit der letzteren durch Fütterung" (Auszug aus dem Jahresbericht der K. Thierarznei-Schule zu Hannover, 1869, S. 127–151).—Virchow's *Archiv*, vol. li. (1870) p. 290.

found the nodules of *Perlsucht* associated with sound lungs and normal bronchial glands. In the lungs I have found either tubercles or larger centres of caseation, or both together, as in the case of the cow described."

I shall now quote one of the inoculation experiments.

Exp. 8. A goat, one year old, was inoculated under the skin with small nodules from a tuberculous cow. Within the first fourteen days there appeared, at the point of inoculation, two walnut-sized nodules, which were at first 1 inch apart, but afterwards became fused. Six months after, the goat was killed for anatomical purposes.

Post-mortem.—(1.) At the point of inoculation there was a grape-like cluster 2 inches long, $1\frac{1}{4}$ inch broad, and $\frac{1}{4}$ to $\frac{1}{3}$ inch thick, composed of nodules from size of a pea to that of a millet seed, round, smooth, yellowish-grey in colour; they lay together loosely, being joined by firm cicatricial tissue. Each consisted of a friable and almost dry caseous interior and *a thick connective-tissue capsule.* (2.) The bronchial glands were enlarged, and the cut surface showed a number of caseous centres, the size of lentils or peas. (3.) The lungs contained six nodules from hazel-nuts to peas in size, and at least thirty nodules the size of from pin-head to millet seed. All lay directly under the pleura, projected more or less, and showed a somewhat firm interior. The smaller nodules were grey and translucent, with an opaque central point; the larger were opaque throughout; the largest formed mulberry-like conglomerates, each nodule having a caseous centre; *on pressure there issued at various points of the cut surface, thick caseous cords, like worms.* The pulmonary pleura showed, on the sharp border of the lung, fringes at certain places, and, over the larger nodules, a filamentous new formation, rich in vessels. No nodules in the abdominal viscera; mesenteric glands normal.

Microscopic.—The caseous contents consisted of formless broken-down masses. The translucent grey substance consisted of large free nuclei, *of somewhat larger round cells distinguishable from the free nuclei by a clear ring* (*of protoplasm*) *between nucleus and cell-membrane*, of larger *multinuclear cells*, and of round heaps of granules. The small cell-elements lay grouped close together. In the larger, less translucent but not yet caseous nodules, the same elements occurred, but there was more connective-tissue intercellular substance, and in places even a fibrous stroma.

Next follow three of the experiments on animals fed with the milk of the tuberculous cow above referred to.

Exp. 12. A healthy and well-nourished calf, eight days old, was fed almost exclusively with milk obtained from the tuberculous cow during the last fifty days of her life, getting at first 1000 grammes daily, and latterly 300 grammes, or an average some 650 grammes daily, and over the whole fifty days of the feeding experiments 30 to 32 kilogrammes of milk. The calf got also some other milk and fodder.

It showed no symptoms of disease, or of disturbed nutrition. One hundred days from the commencement, and fifty days after the end of the feeding experiment, the calf was killed for anatomical purposes.

Post-mortem.—(1) The pleura over the greater part of the sharp border of the right lung was covered with *delicate, red filamentous excrescences, which hung like a fringe about one centimetre over the lung margin*, at certain places being united like a membrane, and in some places containing glancing pin-head nodules; the parietal pleura at various points covered with delicate filamentous new formations, rich in vessels. (2) The lungs showed a variety of nodules, but were otherwise normal. Immediately beneath the pleura, and projecting more or less, lay four nodules the size of peas, and six nodules the size of millet seeds, and in the loose interlobular connective tissue there were eight miliary nodules. The small nodules were the more translucent; all were grey in colour and of firm texture (small delicate new-growths); the cut surface showed several clear points; in one of the larger nodules a yellow cheesy mass lay in the centre. (3) *Bronchial glands* all much swollen, and occupied in their interior with numerous pin-head sized purulent and caseous centres, which here and there contained calcareous matter; these tubercle-centres stood out very conspicuously on section. (4) *Mesenteric glands* all much swollen, and in places nodulated on the surface, of the size of walnuts, the half next the intestine being most swollen. The section showed, especially in the nodulated enlargements, the same picture, but more pronounced, as in the bronchial glands. *All these diseased glands were exactly like the recently affected lymphatic glands in Perlsucht of the cow.*

Exp. 13. An eight-month's lamb, fed with milk from the same cow, killed after three months. Among other *post-mortem* appearances [chiefly omitted]; on the sharp margin of each lung a patch of atelectasis the size of a shilling, in which was situated a nodule the size of a bean, abruptly bounded, of grey colour and medullary consistence on section. On microscopic examination, giant-cells were missed from the above nodules, but they contained capillary vessels distended with blood-corpuscles.

Exp. 14. A pig, six to eight weeks old, was fed for twelve days with milk (400 grammes daily) from the same tuberculous cow. It was killed thirty days after the end of the feeding experiment.

Post-mortem.—(1) The whole lower sharp margin of the right lung was covered in some places with a border, in other places with a fringe; *i.e.*, the pleura presented a constricted thickening, composed of filamentous excrescences of 2 mm. diameter and up to 1 cm. in length; the filamentous out-growths contained clear pin-head nodules *surrounded by a wreath of distended blood-vessels.* On dipping the lungs into water, these new formations showed to best advantage. (2) In the right *lung*, middle lobe and parts next mediastinum, were found grey-coloured nodules, the size of a walnut; they lay under the pleura, which here and round about was covered with red villi, rich in vessels; near these nodules, there lay several clear grey miliary

nodules, *surrounded by a circlet of distended blood-vessels.* On section, both kinds showed clear points, and small caseous centres. (3) *Bronchial glands*, and still more the *mesenteric glands*, much swollen, presenting on section numerous caseous centres of miliary size. Liver, spleen, kidneys, and intestine healthy.

In summing up the morbid conditions induced by the experiments, Gerlach found "on the one hand an agreement with the *Perlsucht* of bovine animals, and on the other hand an agreement with tuberculosis as it appears in man and the apes." He found the same grey translucent tubercles as in man and the apes, more particularly in the experiments with rabbits. He continues—"At the same time, the peculiarity (*Eigenthümlichkeit*) of *Perlsucht* is unmistakable, more especially in the experiments of the calf, sheep, and pig (Exp. 12, 13, and 14). In all the nodules there occurred, before the caseous process set in, an organic union of the lymphoid bodies by means of a delicate connective-tissue substance; the latter was especially marked in the large grey nodules, which, on that account, showed a certain resemblance to small sarcomas; and the same large nodules came still further to resemble the new formation of *Perlsucht*, in that even *capillary vessels appeared in them. But quite especially are we reminded of Perlsucht by the growths on the pleura, round the sharp margin of the lung, in the 12th and 14th experiments; they demonstrate to us the beginnings of Perlsucht.*"

The condition referred to in the concluding sentence of the quotation is one that I shall strongly rely on as proving the identity of the disease in the series of cases in man, with the specific disease of the cow. On that point, and in other respects, I shall endeavour to make out an identity of minute details, including certain of those which Gerlach has noted in his experimental inquiry.

The experiments that are still being conducted at Berlin and elsewhere in Prussia, under the direction of Virchow, are a continuation of those of Gerlach on a more extensive scale. Details which could be utilised, as I shall utilise those given by Gerlach, are not yet available. We are assured by Virchow that the experiments have not been altogether free from abiguity as to the general question of communicability, but that, on the whole, more experiments succeed than fail. I must simply refer to the

article by Mr George Fleming, already quoted, for an account of numerous other experiments to the same or an allied purpose. A non-experimental piece of evidence mentioned by Walley may be introduced here:—[1]

"Only a few days ago I received a communication from Mr William Bromley, M.R.C.V.S. of Lancaster, in which he says—'A short time ago two pigs were killed in a farm in this neighbourhood, which had been fed with milk from a cow afterwards found to be the subject of tuberculosis, and from which she died, and upon *post-mortem* examination characteristic pulmonary *and pleural* tubercular lesions were discovered.' In a subsequent letter Mr Bromley further says:—'The mother of the two pigs to which I referred in my last has, within the past few days, been slaughtered. She was was perfectly healthy, no trace of tubercular or other deposits being discoverable in any part of her body.'"

IV.—Cases in Man.[2]

Case. 1—*Greyish-white medullary nodules in the lungs, some of them wedge-shaped.*

C. P——, male, aged twenty-one, admitted into Addenbrooke's Hospital 14th April 1880, under Dr Bradbury. History of cough and wasting for several months, and of dyspnœa for several weeks. Physical exploration of chest (details omitted) showed disease chiefly in left lung. After being thirty-six hours in the hospital, he died suddenly. He slept quietly till about two or three minutes before his death; he suddenly began to gasp for breath, and died almost immediately.

Post-mortem.—The pulmonary arteries were searched for a clot, but none was found. The left *lung* contained a number of centres of disease, varying from the size of a walnut to the size of a pea; some of them were in the periphery of the lung, projecting on the pleural surface, others were in the centre. They were remarkable for their white medullary appearance. The centre of the mass was usually softened. In the base of the lung was an extensively excavated mass, into which a branch of the pulmonary artery appeared to open freely, although there was no appearance of hæmorrhage having taken place. The right lung contained only one mass, which was felt as an isolated nodule in the midst of the compressible lung substance; it occupied

[1] *Loc. cit.* p. 155

[2] I am much indebted to Mr A. Shaun, house-physician at Addenbrooke's Hospital, for the use of his notes of the cases. I was present at the *post-mortem* examination of all but two of the cases, and the morbid anatomy is chiefly compiled either from my observations then made, or from the subsequent examination of the material preserved.

the hinder border of the lower lobe at its upper margin, and it was distinctly wedge-shaped, about an inch and a half long, of the same medullary consistence and colour as in the other lung, and softened in the centre. The *spleen* was very large, and the surface of it was covered with small flat white bodies of a pearly appearance, such as are sometimes described as occurring on the spleen without any particular pathological significance being assigned to them.

No material was preserved from this case for miscroscopic examination. The nodules in the lungs were of exactly the same colour and consistence as those of the next case; they differed from ordinary tubercles by their vastly greater size, and by having occasionally the shape of a wedge, and they differed from secondary tumours in their greyish-white colour.

CASE 2.—*Greyish-white medullary nodules in the lungs, some of them large and wedge-shaped, most of them small; tuberculosis of serous membranes.*

E. P——, female, aged seventeen, admitted into Addenbrooke's Hospital on the 14th April, under Dr Bradbury. Pulmonary symptoms since four months. On admission, physical signs of disease in lungs (details omitted); fluctuations between morning and evening temperature (*e.g.*, 21st April, morning 100·°8, evening 103°); stupor, sordes, dry tongue, vomiting, delirium at night. Epileptiform fits on 17th and 21st. On the day before death, paralysis of left arm and leg; duskiness of face and rapid respiration preceded death on the 27th.

Post-mortem.—Body wasted. Left *lung* adherent, especially to diaphragm, its pleural surface covered with adhesions containing translucent tubercles. The upper lobe was of a healthy rose-red colour. In the lower lobe, near its upper and posterior angle, was a single well-marked wedge-shaped embolic infarct, 1 inch long and nearly 1 inch broad at base, of greyish-white medullary colour, into which a branch of pulmonary artery entered underneath the thin end. The wedge-shaped area of white substance was composed of a number of round masses, the size of peas or smaller, touching each other. There was another whitish mass at the extreme base, where the lung adhered to the diaphragm. A number of smaller white masses, with round central space, as if lined by a membrane. The right lung contained only the smaller kind of nodules. The *pleura* was studded with minute nodules. *Bronchial glands* enlarged. The peritoneal surface of the *diaphragm* on the right side was the seat of a most remarkable eruption of large, flat, sometimes confluent and lobulated nodules, from the size of a split pea downwards. This eruption was more like that of tumour infection of the serous membranes. The same kind of flat nodules occured in the peritoneum covering the back of the bladder, and in the parietal peritoneum of the right iliac fossa. On the broad ligaments and surface of uterus the nodules were smaller, more glancing and sessile. The left *Fallopian tube* contained, about an inch

from its open end, a nodule about the size of a bean, broken down in the centre. This was not observed until it had been sometime in spirit, and the character of the growth could not be made out satisfactorily. There was an embolic infarct in the anterior end of the temporo-sphenoidal lobe of the *right hemisphere*, yellow softening extending for a short distance on each side of the middle cerebral arterial branch. Miliary tubercles in the *Sylvian fissure* on both sides.

This case has furnished several of the illustrations in the Plates. The wedge-shaped mass in the left lung is represented at the upper part of Plate III. The original freshness of colour of the new formation had been lost before the drawing was made; it suggested, when first seen, the medullary whiteness of a secondary tumour, but it was at the same time more opaque, yellowish or grey. The microscopic drawings on Plate IV. are both made from the same wedge-shaped nodule. With the naked eye, one can see that it is made up of the confluence of several round nodules, and these, again, resolve themselves under the microscope into many small tubercles. The tubercles are interstitial formations in the connective tissue of the lung; they have a tendency to necrosis in the centre, the necrotic and sometimes softened centre breaking away, by a very uniform margin, from the growing and vascular periphery (fig. 11, Plate IV.) The central tubercle of the same figure shows a number of giant-cells, and vessels penetrating into the centre of it. The tubercle of fig. 12 (Plate IV.) represents a very usual and characteristic appearance; the nodule is surrounded by a remarkable wreath or circlet of wide blood-vessels of capillary structure, distended with blood; a small vessel passes right through the substance of the tubercle, and several others are found in its periphery.

To the naked eye, the smaller whitish nodules that occurred throughout the right lung had a peculiarity which I shall have often to refer to; on the cut surface, they appeared sometimes to be perforated with a narrow lumen, the appearance suggesting the broken stem of a clay pipe or a piece of macaroni; at other times, the section showed them to be hemispherical bodies with the centre excavated to a limited extent, and with a substantial thick wall, the interior being uneven.

The enlarged bronchial glands were found, on microscopic examination, to contain tubercles, as in fig. 14, Plate V., from

another case. The remarkable appearance represented in fig. 3, Plate II. is taken from this case. The whole under surface of the diaphragm, on the right side, corresponding to its area of contact with the liver, was covered with that kind of eruption. The tubercles were large and flat, sometimes partly free from the surface, and surrounded by filamentous tissue. Examined with the microscope, some were found to consist of several centres of new formation, while in others the interior had undergone a general necrosis, and it was only round the periphery that any structure could be seen. The structure is that of fig. 15, Plate VI., from another case. It is the tubercle composed of giant-cells, of other large cells with one or more nuclei and resembling epithelial cells, and of lymphoid cells,—the tubercle spoken of by Schüppel and by Rindfleisch, about which I shall have more to say afterwards.

CASE 3.—*Typical acute tuberculosis in a child; remarkable pleural outgrowths; whiteness and large size of the lung nodules.*

A. T——, girl, aged eight years, admitted into Addenbrooke's Hospital on the 22d April, under Dr Bradbury. Typical case of acute tuberculosis in a child; first signs of it five weeks before. Died on the 2d May.

Post-mortem.—Large packet of caseous *bronchial glands.* Abundant tubercles on *pleura,* both pulmonary and parietal; the tubercles were white in colour, sessile, and even pedunculated. Both *lungs* were full of tubercles of unusually large size, and white medullary substance. At the right apex a dense collection of white nodules, having the general outline of a wedge, with some lung-tissue within the outline not occupied by the white substance. The scattered white nodules appeared often to be perforated in the centre by a smooth-walled aperture. Tubercles on the surface of the *spleen* and in the *fissure of Sylvius.*

From this case is taken the coloured drawing (fig. 5, Plate II.), showing the outgrowths on the pleura. I have preserved one of the lungs entire, and one may observe on the surface of it a considerable variety of the characteristic pleural outgrowths—flat, sessile, pendulous, tongue-shaped, or sometimes round, and arranged in a row like a string of pearls. The microscopic drawing (fig. 13, Plate V.) is taken from the wedge-shaped nodule in one of the lungs of this case. It shows a tubercle surrounded by an extensive plexus or wreath of wide blood-vessels, distended with blood.

The enlarged bronchial glands showed, in the microscopic

examination, the same appearance of tuberculosis of the lymphatic glands as is figured in fig. 14, Plate V., taken from Case 5. They were, however, more generally caseated, and it was only in the peripheral and more translucent portions that giant-cells and the other indications of the presence of minute tuberculous centres could be detected.

CASE 4.—*Lung containing several sloughing or putrid cavities; large round tubercles in the intervening lung substance.*

J. B——, male, aged forty years, admitted into Addenbrooke's Hospital on the 9th May, under Dr Bradbury. Pulmonary symptoms said to have existed for two years. On admission: Face congested; tremors of the tongue and facial muscles; much prostration; frequent cough, with expectoration of very offensive purulent sputa. Evening temperature, 104°·2; next morning, 100°. Physical signs of lung disease on left side (details omitted). Before death his dyspnœa increased much; face much congested; perspiration on forehead. Died on the 13th May.

Post-mortem.—Remarkable appearance in thorax. *Bronchial glands* formed a diffluent white mass, like the softer variety of lymphosarcoma. Left *lung* firmly adherent; extensively œdematous; contained a number of gangrenous cavities, one of them (on the periphery) distinctly wedge-shaped; and, in the intervals between the cavities, the lung-tissue was occupied by a number of greyish nodules, of uniform size, as large as peas. The bronchial mucous membrane intensely congested. I did not see the right lung, but the note is that it "contained a considerable quantity of caseous substance, just beginning to break down."

None of the organs from this case were kept for examination. The case was evidently one of intense or virulent infection. The cavities had resulted from the breaking down of solid masses, one at least of which, on the periphery, had been wedge-shaped. Their interior was formed by what might be called an uneven membrane, of a greyish sloughing appearance. A striking feature of the case was the occurrence of a large number of round nodules, all about the size of peas, of dark-grey colour, situated in the œdematous lung tissue between the cavities.

CASE 5.—*Enormous cluster of enlarged portal lymphatic glands containing round nodules; bronchial and mesenteric glands also enlarged; characteristic outgrowths of the serous membranes; tubercles and closed vomicæ in the lungs; large encapsuled tubercles of liver and spleen.*

J. B——, male, aged eighteen, admitted into Addenbrooke's Hospital on the 6th March, under Dr Latham. Five months before, he had to

give up his occupation of baker on account of weakness and shortness of breath. During the last month the dyspnœa has been constantly present. Four days before admission he was obliged to take to his bed. Physical exploration of chest reveals disease on both sides (details omitted). Delirious next day, and picking the bedclothes. Died on the 8th.

Post-mortem.—The parietal *pleura* was thickly studded in parts with tubercles. A few adhesions at base of both lungs. Glancing whitish tubercles all over the surface of the lungs; same on the *spleen*, but more distinctly pedunculated, and sometimes tongue-shaped. The peritoneal surface of the *diaphragm* was thickly covered with large flat nodules, exactly as in Case 2. *Intestines* showed no appearance of tuberculosis. The striking feature of the *post-mortem* examination was the condition of the *portal glands*. They hung down from the portal fissure as an extensive tuberous mass, about 5 inches long; the glands composing it were united by connective tissue, but they were rarely confluent; some of them were very nearly the size of a hen's egg. The portal vein and the splenic and superior mesenteric before their junction were closely involved in the growth, the glands appearing to grow into their walls. The substance of the growth was very firm, hard, creaking under the knife, brownish yellow (like the embolic infarct of Case 10). This kind of substance occurred in each gland in the form of several round centres, separated by bands of translucent tissue, the whole being enclosed in a thick translucent capsule. There were several *bronchial glands* which presented exactly the same appearance of round yellowish-brown nodules, the size of peas, scattered through their black pigmented substance. Nodules, also the size of peas, and surrounded by a translucent thick capsule, in liver and spleen, along with smaller tubercles. Small tubercles in left Sylvian fissure. The condition of the *lungs* was like that of the next case, and will be referred to under it.

This is one of the most complete cases of the series. The characteristic appearance of closed vomicæ in the lung (what might be called the "crumpet-lung") in the coloured drawing (fig. 9, Plate III.) is taken from the left apex in this case. The drawing of the characteristic flat and pendulous outgrowths on the surface of the spleen (fig. 6, Plate II.) is also taken from it. The pleural outgrowths were equally characteristic, and the eruption of flat nodules on the under surface of the diaphragm, corresponding to its area of contact with the liver, was precisely the same as that of Case 2, drawn in fig. 3, Plate II. The microscopic characters were also the same.

The thoracic and abdominal lymphatic glands were equally characteristic; the cluster of enlarged portal glands, a lobulated mass as large as a cocoa-nut hanging down from the portal fissure, at once arrested the attention. The glands were for the

most part hard and tough, creaking under the knife, and the cut surface showed them to contain each several round nodules, up to the size of peas, bounded by a well-defined belt of more translucent tissue. The section of one of the bronchial glands is shown in fig. 10, Plate III. A larger drawing, to the same effect, might have been obtained from one of the portal glands, which had not, however, been cut into at the time the drawings were being made. The microscopic appearance of the tubercles in one of the bronchial lymphatic glands is shown in fig. 14, Plate V. I shall defer notice of it until I treat of the condition of the lymphatic glands generally.

The liver and spleen each contained a number of large round tubercles, up to the size of peas, which were remarkable for their well-marked peripheral belt of translucent tissue, simulating a capsule. Numerous minute tubercles, detected only in the microscopic sections, occurred near the larger nodules, both in the liver and spleen.

CASE 6.—*Rapid tuberculosis in a previously healthy man, commencing from the tonsil; tubercles and closed vomicæ in the lungs.*

T. C.——, male, aged fifty-seven, admitted into Addenbrooke's Hospital on 11th February, under Dr Latham. Quite well till seven weeks ago; then had quinsy. The throat was lanced by a surgeon, and a quantity of matter evacuated. Lost his voice at that time, and still speaks in a whisper. No cough or night-sweating, but has had sometimes shortness of breath. On admission there is no pain in chest or elsewhere, but constant slight dyspnœa. Temperature on two successive days: 101°·8 morning, and 103°·4 evening; 100°·8 morning, and 103°·8 evening. Before death severe dyspnœa. Death on 15th February.

Post-mortem.—Both *lungs* firmly adherent all round. In the right lung a cavity the size of a walnut at the apex; the rest of the lung thickly studded with tubercles, smaller and more translucent in upper part, greyish-white, opaque, and becoming confluent at the base. The special interest centres in the condition of the left apex, which exactly resembled the condition in the corresponding apex of Case 5, and which is probably characteristic of the bovine disease. The lung was as if honey-combed with smooth-walled cavities from the size of a pin-head to that of a large pea, or even a hazel-nut. To use a homely illustration, the lung resembled the substance of a crumpet. I at first took this condition for bronchiectasis; but the cavities are found to result from the central softening of large tuberculous nodules, the periphery of the nodules being formed of translucent and highly vascular tissue, which remains as a smooth membrane like the wall of a cyst. Solid whitish nodules

of various sizes, up to that of a pea, were seated as if on the outer walls of the excavations, or in the lung-tissue between them.

The chief interest of this case lies in the rapid course of tuberculosis in a previously healthy man, aged fifty-seven, and in the exact resemblance of the condition in the lung to that of Case 5. The coloured drawing (fig. 9, Plate III.), taken from the latter, might have been matched from the left apex of the lung in this case.

CASE 7.—*Cavities in the lungs, with dense semi-cartilaginous walls; encapsuled large round nodules in the lungs; pendulous outgrowths on pleura, and beaded condition of the sharp margin of the lung.*

A. P——, female, aged eighteen, admitted moribund into Addenbrooke's Hospital on 27th Feb., under Dr Latham. Died shortly after.

Post-mortem.—Body well nourished. The whole upper lobe of the left *lung* was occupied by one enormous cyst or cavity, on the inner surface of which there was not a trace of friable caseous substance. Its wall was compact like the wall of a cyst, and its inner surface was smooth or slightly granulated, and of a red colour, as if from blood. In the walls of the cyst and in other parts of the lung there were hard brownish-yellow opaque nodules from the size of a pea to that of a hazel-nut, sometimes slightly confluent, surrounded by a thick translucent capsule, and with lighter or caseous points in their centre. In the right lung, at the apex, there was a round cavity with a uniform inner surface, the size of a billiard-ball; its walls were of great density or firmness, creaking under the knife; a branch of the pulmonary artery appeared to end in its periphery. In the lung-substance, round the cavity, the same yellowish-brown encapsuled nodules as in the left lung. In the middle lobe of the lung the opaque nodules were smaller and more uniform in size, and at the extreme base they formed grape-like clusters. There were extensive pleuritic adhesions on both sides. On the *surface of the lung* there were a number of flat pendulous nodules, one of which, about three-eighths of an inch in diameter, was suspended by a piece of the adhesion, like a small medallion. Round the sharp margin of the right lower lobe there were a few small pleural nodules, partly fused into a cord, giving the margin a beaded appearance.

From this case is taken the drawing of the sharp margin of the lung, lower lobe (fig. 4, Plate II.), showing an appearance of flat nodular outgrowths, constricted to a kind of pedicle at the base, fused into a cord towards the right-hand side. This appearance occurs in other cases, and is probably characteristic. The largest pleural nodule that I have found in any of the cases

occurred in this case. It was about three-eighths of an inch in diameter, flat and transparent (suggesting fat tissue), and suspended by a long and narrow band of connective tissue. The pleural surface elsewhere showed the usual varieties of the characteristic pleural outgrowths.

From this case also is taken the coloured drawing (fig. 8, Plate III.), showing large round encapsuled nodules in the lung substance. I believe the appearance to be very characteristic of the more chronic form of the disease in the lung.

The peculiar appearance of fig. 17, Plate VI., is taken from this case; it occurred uniformly in connection with the smaller tubercles in the lower lobe. The tubercle-nodule has evidently broken through and grown into the nearest bronchus. The same encroaching process probably takes place in the case of larger nodules and larger bronchi, and would account for the communication sometimes found to exist between the softened centre, or the cavity of the nodule, and the lumen of the bronchus.

CASE 8.—*Rapid tuberculosis in a previously healthy man; characteristic pleural outgrowths; small greyish-white medullary nodules, with softened centres, throughout both lungs; swollen bronchial glands.*

C. F——, male, aged twenty-eight years, fireman, Ely, admitted into Addenbrooke's Hospital on 4th June, under Dr Bradbury. Had good health till six weeks ago; then began to have a dry cough. A month ago felt he was losing strength, and noticed that he was losing flesh. Three weeks ago the cough became severe, and he complained of dyspnœa. The cough and dyspnœa have gone on increasing till admission. Sleep much disturbed during the last few nights. Has not felt feverish; no sweating.

Present condition—Face extremely dusky; considerable dyspnœa; small quantity of muco-purulent expectoration. The patient is a well-built man, and shows no sign of emaciation. Pulmonary resonance impaired somewhat at right base; abundant medium-sized crepitation at both bases; no increase of voice sound; chest elsewhere resonant. Fine crepitation heard in almost every part of chest, with occasional rhonchi. Heart sounds healthy.

His general condition appeared to improve for the next week or two; the cough and expectoration continued; crepitation became coarser. The temperature was generally between 99° and 100° in the morning, and a degree higher in the evening. On 21st June there

nodules, *surrounded by a circlet of distended blood-vessels.* On section, both kinds showed clear points, and small caseous centres. (3) *Bronchial glands*, and still more the *mesenteric glands*, much swollen, presenting on section numerous caseous centres of miliary size. Liver, spleen, kidneys, and intestine healthy.

In summing up the morbid conditions induced by the experiments, Gerlach found "on the one hand an agreement with the *Perlsucht* of bovine animals, and on the other hand an agreement with tuberculosis as it appears in man and the apes." He found the same grey translucent tubercles as in man and the apes, more particularly in the experiments with rabbits. He continues—"At the same time, the peculiarity (*Eigenthümlichkeit*) of *Perlsucht* is unmistakable, more especially in the experiments of the calf, sheep, and pig (Exp. 12, 13, and 14). In all the nodules there occurred, before the caseous process set in, an organic union of the lymphoid bodies by means of a delicate connective-tissue substance; the latter was especially marked in the large grey nodules, which, on that account, showed a certain resemblance to small sarcomas; and the same large nodules came still further to resemble the new formation of *Perlsucht*, in that even *capillary vessels appeared in them. But quite especially are we reminded of Perlsucht by the growths on the pleura, round the sharp margin of the lung, in the 12th and 14th experiments; they demonstrate to us the beginnings of Perlsucht.*"

The condition referred to in the concluding sentence of the quotation is one that I shall strongly rely on as proving the identity of the disease in the series of cases in man, with the specific disease of the cow. On that point, and in other respects, I shall endeavour to make out an identity of minute details, including certain of those which Gerlach has noted in his experimental inquiry.

The experiments that are still being conducted at Berlin and elsewhere in Prussia, under the direction of Virchow, are a continuation of those of Gerlach on a more extensive scale. Details which could be utilised, as I shall utilise those given by Gerlach, are not yet available. We are assured by Virchow that the experiments have not been altogether free from abiguity as to the general question of communicability, but that, on the whole, more experiments succeed than fail. I must simply refer to the

article by Mr George Fleming, already quoted, for an account of numerous other experiments to the same or an allied purpose. A non-experimental piece of evidence mentioned by Walley may be introduced here:—[1]

"Only a few days ago I received a communication from Mr William Bromley, M.R.C.V.S. of Lancaster, in which he says—'A short time ago two pigs were killed in a farm in this neighbourhood, which had been fed with milk from a cow afterwards found to be the subject of tuberculosis, and from which she died, and upon *post-mortem* examination characteristic pulmonary *and pleural* tubercular lesions were discovered.' In a subsequent letter Mr Bromley further says:—'The mother of the two pigs to which I referred in my last has, within the past few days, been slaughtered. She was was perfectly healthy, no trace of tubercular or other deposits being discoverable in any part of her body.'"

IV.—Cases in Man.[2]

Case. 1—*Greyish-white medullary nodules in the lungs, some of them wedge-shaped.*

C. P——, male, aged twenty-one, admitted into Addenbrooke's Hospital 14th April 1880, under Dr Bradbury. History of cough and wasting for several months, and of dyspnœa for several weeks. Physical exploration of chest (details omitted) showed disease chiefly in left lung. After being thirty-six hours in the hospital, he died suddenly. He slept quietly till about two or three minutes before his death; he suddenly began to gasp for breath, and died almost immediately.

Post-mortem.—The pulmonary arteries were searched for a clot, but none was found. The left *lung* contained a number of centres of disease, varying from the size of a walnut to the size of a pea; some of them were in the periphery of the lung, projecting on the pleural surface, others were in the centre. They were remarkable for their white medullary appearance. The centre of the mass was usually softened. In the base of the lung was an extensively excavated mass, into which a branch of the pulmonary artery appeared to open freely, although there was no appearance of hæmorrhage having taken place. The right lung contained only one mass, which was felt as an isolated nodule in the midst of the compressible lung substance; it occupied

[1] *Loc. cit.* p. 155

[2] I am much indebted to Mr A. Shann, house-physician at Addenbrooke's Hospital, for the use of his notes of the cases. I was present at the *post-mortem* examination of all but two of the cases, and the morbid anatomy is chiefly compiled either from my observations then made, or from the subsequent examination of the material preserved.

Post-mortem, 1st July.—A few soft adhesions in both pleural sacs. The *pulmonary pleura* at the base of one of the lungs showed the leaf-like "duckweed" variety of pleural outgrowths in the most exquisite form; the margin of the lung was occupied by a cord-like border of new growth for a considerable distance, and on the adjoining convex surface the same rounded cord-like outgrowths occurred, some of them projecting half an inch free from the surface (fig. 1, Plate I.). In the substance of both *lungs* whitish tubercles of considerable size could be seen dotted about under the surface; on section both lungs were found to be densely studded with very fine miliary tubercles. *Heart* very little larger than natural; mitral orifice stenosed, admitting the end of the middle finger; vegetations, apparently of recent formation, on the auricular surface of the valves, which were much thickened; aortic valves also thickened, and covered with villous-like vegetations. *Liver* partly adherent to diaphragm, and, where free, covered with the kind of flat leaf-like outgrowths represented in fig. 2, Plate I. Besides these, a few translucent bodies, like miliary tubercles, were seen on the surface. Substance healthy. *Spleen* adherent to diaphragm. *Intestine*, for a space of about 6 inches in the right iliac region, was studded on the serous surface with a narrow tract of villous outgrowths, up to a quarter of an inch in length; they occupied the free border of the bowel exactly opposite the mesenteric attachment. *Mesenteric glands*, one of them enlarged to the size of a hen's egg, hard, calcareous, feeling like a stone embedded in the mesentery; near it some quite small glands also petrified with chalky substance. The left *ovary* was 4 inches long in its long axis; the surface ecchymosed; the centre softened (leaving a periphery of solid substance about three-eighths of an inch thick), and containing flaky caseous matter with an offensive smell.

From this case I have had drawn what I am inclined to consider a perfectly typical form of the pleural outgrowths in bovine tuberculosis. It is the coloured drawing, fig. 1, Plate I., representing the concave base and the adjacent rounded lateral aspect of the lung, with the intervening margin. The concave base shows the "duckweed" condition, the rounded lateral surface shows some typical examples of the cord-like outgrowths, and the margin shows the beaded or corded condition, of which fig. 4, Plate II., is another example. On these characters alone I should be inclined to rest the identification of the form of disease in this case. The liver, where not adherent, showed the appearance of fig. 2. The growths are well-defined excrescences of the peritoneal capsule, and it is not difficult to see that they acquire their large size from the confluence of a number of the smaller leaf-like outgrowths of fig. 1. It is a remarkable fact that a narrow strip of villous outgrowths was

found also over a limited portion of the intestinal serous membrane in the right iliac region.

The enormous size and calcareous infiltration of one of the mesenteric glands is significant; the quite small glands found near the large one were also calcareous.

The case may appear to be complicated by the existence of a so-called scrofulous ovary. I shall discuss that point later. Another interesting complication is the formation of vegetations on the mitral and aortic valves.

Some of the tubercles in the lungs were large and of greyish-white colour, but the pulmonary lesion as a whole (apart from the pleural) is not distinctive.

CASE 10.—*Typhoid fever six months before; tuberculosis of lungs and peritoneum; two healed ulcers of ileum; wedge-shaped infarct of new growth in one lung.*

S. J——, female, aged thirty-eight, admitted into Addenbrooke's Hospital on March 13th, under Dr Bradbury. Had typhoid fever in August 1879, and has never been quite well since. Now admitted for certain ill-defined abdominal symptoms (details omitted). There was great fluctuation between morning and evening temperature, the record on April 8th, for example, being 99°·2 morning, and 104°·5 evening. Acute tuberculosis was diagnosed. On April 19th she became much worse, the face becoming dusky and the respiration rapid. Died on 20th.

Post-mortem.—Both *lungs* full of translucent miliary tubercles of a very small size. Small translucent tubercles on the *pleura*. In the lower lobe of the right lung there was a well-marked embolic infarct, wedge-shaped, about two inches long, and one inch and a quarter broad at its base on the pleura. It was quite firm and somewhat tough, not at all broken down, of dry texture, and brownish-yellow colour, not everywhere of the same shade. In the abdomen there was recent peritonitis, the intestines being glued together. The whole *peritoneum* was covered with an eruption of large flat nodules, up to the size of a split pea, sometimes confluent, most abundant in the right iliac region, where there were old adhesions. They contained minute points of black pigment. Recalling the fact of typhoid fever six months before, and that healed typhoid ulcers may have black pigment in the cicatrix, I referred the peritoneal eruption to that source, and proceeded to unravel the matted intestines, so as to examine the *ileum*. I found only two healed ulcers; one of them was of considerable size, just above the valve, and another half an inch in diameter, about a foot higher up. The latter I kept for microscopic examination, and a thickening, partly in the floor of the cicatricial depression, but more to one side of it, has afforded very remarkable

specimens. Both cicatricial depressions had minute points of black pigment in their extreme centre. The peritoneal covering of the *liver* and *spleen* was studded with the same large flat tubercles as elsewhere. *Mesenteric glands* not altered in colour nor enlarged.

From this case I have taken the microscopic drawing, fig. 15, Plate VI., showing the structure in the thickened base of one of the healed ulcers in the ileum; and I shall discuss in another section the large and important question that the case raises with reference to typhoid fever, and especially with reference to epidemics of typhoid fever traceable to the milk of a particular dairy. The large flat tubercles were precisely the same as those of Cases 2 and 5; over the intestines, especially of the right iliac region, they were often raised clear of the serous surface, and situated in the meshes of a filamentous new growth covering the peritoneum. I unfortunately neglected to keep the remarkable wedge-shaped mass that occurred in one lung. It had exactly the form and position of an embolic infarct; it was hard, firm, and tough, with a brownish-yellow colour, broken by paler or more translucent lines, and it resembled most nearly the nodules drawn in fig. 8, Plate III.

CASE 11.—*Symptoms of acute rheumatism; afterwards cough and wasting, with continued high evening temperature; white medullary tubercles of lungs; tuberculous ulcers of intestine; caseous thoracic and abdominal lymphatic glands.*

L. D——, female, fifteen, Cambridge, admitted into Addenbrooke's Hospital on 5th May 1880, under Dr Bradbury. Acute rheumatism (?) in 1877. Typhoid fever in 1878. Three weeks ago began to suffer from headache and pains in the shoulder-joints and dorsal region of spine. Has had more or less pain ever since in arms and back; the pain is not limited to the joints. Never any pain in the knees or ankles. Has been feverish throughout; perspiration also noticed to be excessive. On admission, face flushed, skin hot, but not moister than natural. Complains of pains in both shoulders and arms, and also of pain in the left hypochondrium. No swelling of any of the joints. Tongue much coated. The temperature was 103°·2 on the evening of admission, and 100°·2 next morning. Subsequently it was at or somewhat over the normal in the morning, and a degree higher in the evening, until three weeks after admission, when it began to be about 100° in the morning and 103° in the evening. During the period of lowered temperature the pains were only occasional; frequent free perspiration; strong rheumatic odour. The heart-sounds were

natural, and there were no pulmonary symptoms. When the temperature began to rise on 30th May the patient complained of nothing. On 8th June frequent dry cough is noted; no other complaint; the respiratory sounds under the left clavicle were harsh. The temperature keeps at about 103° in the evening and from three to four degrees lower in the morning. On the 17th June and following days the cough is troublesome; some muco-purulent expectoration; perspires very freely at night: abundant sonorous rhonchi over whole of left pectoral region; no loss of resonance; crepitation most abundant behind, in subspinous fossa. Some albumen in urine. Cheeks generally flushed. Losing flesh. From 22d to 27th June, the temperature is noted between 100° and 101° for both morning and evening. On 27th the evening temperature again rose towards 103°, falling three degrees in the morning. The temperature remained of much the same character till death, occasionally reaching 104° at night. On 2d July there was abundant sharp crepitation of large or medium size over the whole of left chest; less marked on right side. No dulness. Breathing rather short. These symptoms continued till death, with progressive wasting, dryness of skin, flushed face, some œdema of feet. Sordes. Dyspnœa. Wandering. Death at 9 P.M. on 1st September.

Post-mortem on 2d September.—Body emaciated; considerable œdema of feet. *Pleura*, long filamentous cords growing out from sharp margin of lower lobe. Left lung firmly adherent to chest-wall laterally, and to diaphragm at base. *Lung* substance, in the lower lobes shotty to the feel, from presence of a few scattered whitish tubercles. In middle portion, and at apex of right lung, large white nodules, the size of peas, yielding, on pressure, white milky or creamy puriform substance, and, when excavated, presenting the appearance of smooth-walled cavities. The formation in the left apex was most extensively broken down, the whole upper lobe of the lung being occupied with a semi-gangrenous excavation. In another part of the lung occurred an oval cavity about one inch in length, with a thick vascular wall, and showing in its interior the appearance of a red granulating surface. *Intestine* contained numerous ulcers, the largest being in the ileum, of round shape, one inch, more or less, in diameter. The floor of the ulcer was occupied by a number of scattered and distinct small whitish tubercles, which projected on the peritoneal covering of the intestine. The highest ulcer occurred within three inches of the pylorus, of the size of a pea, situated on the side and base of one of the valvular folds. The *lymphatic glands* in the mesentery, especially at its upper part, much enlarged, some caseous, one or two with calcareous deposit in centre, and many of them showing a number of small independent centres of new formation, of medullary white colour. Those near the cæcum were of deep red colour, and soft. The enlarged glands extended into the thorax behind the aorta, and on both sides of the thoracic duct; the latter was dissected clear of the glands for a considerable distance towards the neck, and did not appear to have any new growth within or upon it. The bronchial cluster was much enlarged, and the enlarged chain extended

upwards into the neck. In one of the bronchial glands an interesting appearance was found, which throws light on the softening of the lung nodules; the white medullary nodule within it had become softened in the centre, and the cross-section had exactly that macaroni-like appearance so often mentioned in the preceding cases as having been observed in the lung nodules. A single small translucent nodule was observed on the surface of the liver, and one also on the spleen.

The condition of the lungs in this case was like that observed in several other cases. The noteworthy points are the medullary softness and whitish colour of the nodules, and their tendency to form a more or less sharply defined excavation in the centre. The extensive implication of the lymphatic glands is significant, as well as the cretaceous deposits in some of them. The isolated round nodules or centres within the individual lymphatic glands had, in the less advanced stages, the same whitish colour as the nodules in the lungs. The tubercles in the floor of the intestinal ulcers had also that colour; to speak of them either as grey or as yellow would not be strictly accurate.

CASE 12.—*Rapid tuberculosis; unusually high evening temperature; greyish-white medullary nodules in the lung, and wedge-shaped masses; white medullary swelling and ulceration of follicles of intestine.*

G. E——, twenty-seven, male, tailor, Ely, admitted into Addenbrooke's Hospital on 4th August 1880, under Dr Bradbury. Family history good; no consumption. Eight years ago lost a leg through railway accident. Health good until seven weeks ago; began to suffer from cough, and lost appetite and flesh. During the past three weeks there has been profuse night sweating; never any hæmoptysis. Since two weeks has noticed that he becomes feverish about 6 P.M.

On admission—Pale sickly aspect; thin; scars on neck, apparently from suppurating glands in childhood; cough, with frothy greenish expectoration. Bad appetite. Tongue coated. Trace of albumen in urine. Percussion note not good at apex of either lung. Respiratory sounds throughout the chest in front normal; resonance behind good; respiratory sounds less distinct at right base than at left. The temperature throughout his whole illness in hospital had a tolerably uniform character; it averaged about 103°·5 in the evening, and was from two to three degrees (and occasionally four degrees) lower in the morning. On four occasions it reached to near 105°, and on the afternoon on which he died it stood at 107°·4. On 19th August the examination of the chest revealed—Expansion good; harsh expiratory sound over left apex; occasional minute râles. Percussion note dull behind, particularly over left base. Vocal fremitus and resonance not increased. Tubular breath-

ing over left lung posteriorly. Muco-purulent expectoration. Feels faint. On 24th August—Absolute dulness in both supraclavicular regions. Tubular breathing below both clavicles. Bronchial breathing over right lung. Crepitation at left base. Some blood in sputa.

On 3d September he did not seem altogether conscious; later, very excited; subsultus tendinum; face livid. Death at 1.30 P.M.

Post-mortem, 4th September.—Body emaciated; right foot has been amputated above ankle. One or two soft and vascular adhesions of *left pleura*. Adhesions of lobe to lobe in *left lung;* in the upper lobe, near the outer surface, a broad shallow cavity, with whitish puriform substance in its interior, and irregular walls; in lower lobe a number of smooth-walled cavities from ¼ in. to 2 in. diameter, containing whitish puriform substance. In *right lung* (which was adherent), several nodules could be felt in the midst of the compressible lung substance, mostly near the surface; on section, one mass in particular was found to be wedge-shaped, and made up of the confluence of a number of smaller round whitish nodules; it was broken down at the apex. Another larger and very distinct wedge occurred, its base on the pleura being 1½ inch square; it was uniformly firm, and resembled grey hepatisation; the portion of pleura exactly corresponding to its base was covered by a layer of fibrinous membrane. The most dependent anterior portion of the upper lobe was in a state of grey hepatisation. The thin lower margin of the lung was shotty, with a few whitish nodules; its pleural surface showed a few of the leaf-like outgrowths. The bronchi did not appear to communicate in any instance with the cavities in the lungs. On pressure, small cylindrical masses of whitish substance, like worms, could be made to issue from the centre of the better preserved nodules. In the *intestine*, the lymphatic follicles were everywhere swollen and of medullary white appearance. They were observed of small size throughout the whole jejunum; with here and there a larger one, prominent, injected, and ulcerated. The highest Peyer's patch was found at a point before the valvular folds had ceased; it was 4 inches long and about ¾ inch wide, and it was studded all round the margin and partly in its centre with swollen and white medullary follicles, a small injected vessel appearing to lead up to each of the swollen follicles. Peyer's patches, in a similar condition, were found to the number of ten, and near the ileo-cæcal valve there were two or three true ulcers with thickened edges. The *mesenteric glands* were not at all conspicuous. The *large intestine* was entirely unaffected. The *brain* and *membranes* were normal.

This case resembled Case 11, which was examined only two days before it, in some particulars. In the lungs in both cases nodules of medullary whiteness occurred, softened at the centre, and yielding at every section of the lung a milky or creamy puriform fluid. The intestinal lesion was not quite the same in the two cases, and in Case 12 the lymphatic glands appeared to be entirely unaffected. Again, in Case 12, the wedge-

shaped character of the lung nodules, already referred to in the earlier cases, was a distinguishing feature. Besides the wedges of medullary substance, made up of the confluence of a number of large round tubercles, there occurred one very large and clean-cut wedge, with compressible lung tissue on both sides of it, which had on section the character of grey pneumonic hepatisation.

V.—The Formations on the Serous Membranes.
(Plates I. and II.)

The task of tracing an identity of structural details between the foregoing cases of tuberculous disease and the specific bovine form of tuberculosis, is one that is attended with the greatest difficulty. I venture to think that if the appearances which I have recorded had been observed and described for the first time in the human subject, the correspondence with the bovine disease would have been made out more easily. But there are few or none of these points of structure that have not been noted before, in one connexion or another; they have been for the most part added to the extensive and perplexing catalogue of the characters of tubercle, as it may be compiled from works on human pathology. My position is that the cases of bovine tuberculosis in man, which have occurred (doubtless in large numbers) in the past, have been, without discrimination, swept into the general heap of tuberculous cases, and the specific characters which they have shown have only served to swell the list of the characters of tubercle regarded as a single and indivisible malady. I think it is possible, however, by a careful attention to minute details of form and structure, to restore such cases to an independent place among the diseases of the human body, and to detach them from the indiscriminate heap of all that is called tubercle. It is usual to say that there are few diseases more Protean than tubercle; but we may safely infer that the Protean characters of tubercle are only a reflex of the confusion in our own minds. Experiments have made it more than probable that the specific bovine disease has in some, if not in many cases, been communicated to man. From the circumstances of the case, the number of persons infected from the cow or ox would, if they occur at all, be infinitely greater than the cases of glanders in man

traceable to the specific disease of the horse. There is a reasonable presumption that such cases make up a considerable part of the cases of tuberculosis observed in medical practice, and, on that hypothesis, it is tolerably certain that we have already incorporated all or most of the characters of the bovine disease, as it appears in the human body, in our current conception of human tuberculosis.

For example, as regards the conditions in the lung, the treatise by Rindfleisch on "Chronic and Acute Tuberculosis,"[1] makes reference, or implies reference, under one head or another to probably the greater part of the characters of the pulmonary lesion which I shall regard as distinctively belonging to the communicated bovine disease. Indeed, the definition of tubercle that Rindfleisch adopts, appears to me to have been mainly determined by the large infusion of the distinctive bovine characters into his general conception of tuberculosis. Again, as regards the lymphatic glands, the conclusive work of Schüppel on "Lymphatic-Gland Tuberculosis"[2] has deprived one of the opportunity of proving for the first time that many cases of apparently simple and primary scrofulosis or caseation of the glands in man are really cases of tuberculosis within the glands, and of so making out an unprejudiced point of identity with the bovine disease. In like manner, the question of the intestinal lesion has grown to be one of great intricacy, and the lesions of the genito-urinary organs have been no less involved among alien matters. It is perhaps the condition of the serous membranes that offers the clearest and least prejudiced ground for establishing an identity with the specific bovine disease, and that is also the lesion that is most distinctive of the bovine disease itself. I shall begin my general resumé with the condition of the serous membranes, and follow with some account of the condition of the lungs, leaving part of the latter subject and all the remaining portions of the inquiry for a subsequent paper.

The formations on the serous membranes in the ox and cow have been so conspicuous a feature of the disease, that they have determined all the various names that the disease has been called by in different countries. Some have even gone so far as

[1] Rindfleisch, in Ziemmsen's *Handbuch*, vol. v. Leipzig, 1874.

[2] Schüppel, *Untersuchungen über Lymphdrüsen-Tuberculose*, Tübingen, 1871.

to say that the disease is confined to the serous membranes and the lymphatic glands; there is, however, abundant evidence that the lungs are affected, and we have the emphatic statement of Gerlach, already quoted, that he has never seen a case of "pearls" on the serous membranes without disease in the lungs and bronchial glands. The "pearls" on the pleura, pericardium, and peritoneum are formations of a very uniform and characteristic appearance, and, according to Virchow, their size should distinguish them from other tubercles. They are, for the most part, an eighth of an inch in diameter, or, as nearly as possible, the same as the leaves of duckweed. It is the curious resemblance to the dense masses of that plant that has suggested the early German name of bovine tuberculosis, viz., *Meerlinsigkeit.* The resemblance consists in the uniform size and flatness (with convex upper surface) of the serous nodules, and in their occurrence in dense masses. That general resemblance is close enough, without bringing in the occurrence of stalks or runners appearing here and there among the leaves. The serous nodules have also a tendency to become confluent, two or three or more uniting partially at their edges to form a broad lobulated patch. They are also apt to become detached from the serous surface out of which they grew, and they are not unfrequently found as if entangled in or supported by a mesh-work of fibres on the surface of the membrane. Such are the most characteristic appearances of the serous eruption. But it may be observed also in its earlier and in its more developed stages. I have already quoted from Walley an account of the mode of origin of the serous-membrane nodules, according to which they begin as vascular villi, within which a certain consolidation or cellular formation takes place, leading to sessile or pedunculated nodules. According to Virchow (*loc. cit.* p. 189), the eruption may sometimes put on the sub-miliary form; "but the formation of nodosities is the rule, and, if their number is very great, the lung is covered by them as stagnant water is with duckweed." It is only occasionally that the large polypoid masses, sometimes weighing several pounds, are found; in the case of the cow, quoted from Gerlach, it is specially noted that the larger growths were wanting.

In the twelve cases in man, which I have recorded, a considerable variety of serous-membrane outgrowths occurred. The flat round

or oval nodules, of the size of duckweed leaves, occurred in at least three cases, the under surface of the diaphragm, where it comes in contact with the liver, being the favourite situation. Fig. 3, Plate II., represents the appearance on the under surface of the diaphragm. The largest nodule that I have found occurred in the pleura in Case 7; it was round and flat, about three-eighths of an inch in diameter, and it hung suspended by a long narrow band like a small medallion. But the most usual kind of outgrowth, one that occurs almost universally in the series of cases, is not so much a solid and firm nodule, as a papular, or button-like, or leaf-like, or villous or tongue-shaped formation of softer texture. The size of them corresponded to the prevailing size of the duckweed leaf, but they wanted the thickness and density of an actual nodule. Fig. 5, Plate II., represents a piece of the lung surface from Case 3, covered with such outgrowths; in this case they were always of an opaque white colour. Fig. 6, in the same Plate, shows a very similar condition of the surface of the spleen in Case 5. Another variety of the same condition is shown in fig. 1, Plate I., from the base of the lung in Case 9. It is hardly possible to avoid the conclusion that there is something quite distinctive and characteristic in this latter appearance. The base of the lung is covered with a number of flat round leaf-like bodies attached to the surface by a somewhat constricted pedicle; they are, for the most part, membranous, and the edges are sometimes turned up, thereby showing the clear space between the pleura and the under surface of the leaf. In the actual specimen, they want the solidity of the duckweed leaf; but that is because they represent an earlier stage of the formation. The earliest condition in which I can identify these outgrowths, is that of a number of red (vascular) papules slightly raised above the surface of the lung in Case 12. The leaf-like outgrowths tend to become confluent, just as the more solid nodules do (see fig. 3, Plate II., from under surface of diaphragm); and the confluence of several of them leads to the appearance of remarkable growths, such as occurred on the upper surface of the liver in the same case (Case 9), and are represented in fig. 2, Plate I. They are of loose delicate texture, as if rarified in the interior, and partly suggestive of collapsed bullæ. Their connexion

with the serous surface is generally by a somewhat constricted short pedicle, and the margin of the leaf-like expansion is always free for a certain distance. The liver, in this case, was partly adherent; the drawing is taken from a portion of it that was not adherent, and there can be no suggestion of the appearances having been produced artificially by the tearing through of adhesions. The same remark applies to the apex of the lung in Case 8 (see notes of cases). There can be no doubt that such outgrowths lead to the formation of adhesions; but it is equally certain that such adhesions are not due to what is assigned as the universal cause of adhesions, viz., pleurisy or peritonitis. A circumscribed patch of such outgrowths may attach themselves by their free extremities or surfaces to the opposite pleura or peritoneum, and so form an adhesion; but pleurisy or peritonitis, as the cause of an adhesion under such circumstances, is entirely out of the question. The true analogy is rather the case that is sometimes seen of an eruption of tumour-nodules on the under surface of the diaphragm, leading to a firm union of the latter with the liver. In Case 9, there occurred also the peculiar narrow band of villous outgrowths on the peritoneum over about six inches of the ileum (see notes of cases).

It remains to mention another and not less important variety of the formations on the serous membranes. It is especially apt to occur round the sharp margins of the lung, more particularly that of the base. In fig. 1, Plate I., the marginal formation is shown, and fig. 4, Plate II. is another representation of the same kind of growth. The formations round the sharp margins of the lung are very commonly met with in the above cases, and they are sometimes *the only indication of the disease present on the serous membranes.* These outgrowths occasionally form a villous or membranous fringe (of which the membranous prolongation on the right hand side of fig. 8, Plate III., may be a more advanced condition), but it is in the form of a number of independent cord-like processes that they are most distinctive. The best examples of them that I have met with are those drawn on the convexity of the lung in fig. 1, Plate I. They sometimes hang free from the surface to the length of half an inch, both on the lateral aspects of the lung (as in the figure) and on its sharp margin; but, in the latter situation, it is usual

to find a braided or corded appearance of the border. In fig. 4, Plate II., the outgrowths on the sharp margin are partly isolated and of unequal height, and on the right hand side they are fused into a straight cord; in both forms, a constriction occurs between the attached margin of the growth and the pleura, forming a sort of pedicle in the isolated growths and a groove for the piece of cord. The margin shown in fig. 1, Plate I., is somewhat more complex; there is a more or less continuous outgrowth of some breadth, like a thick frill, and cord-like outgrowths running above it or alongside of it. Sometimes the formations are quite short, in the form of conical papillæ or warty excrescences, at other times they are long and slender, and occasionally they are in the form of a loop. Generally speaking, an injected vessel or vessels may be made out with a lens, occupying the centre of the outgrowth.

That these formations on the pleura, and more particularly on the thin margin of the lung, are something special and distinctive appears to be beyond doubt. It may be thought, however, that they are too slight in themselves to serve as trustworthy indications of any particular disease. It must be admitted that in most of the cases we have only the beginnings of the serous-membrane eruption; it is only in Cases 2, 5, and 10 that the actual large flat tubercles of *Perlsucht* can be said to have occurred fully developed. The more usual condition is only the first indication of the serous-membrane lesion, but it is quite conceivable that the bovine disease, when it is communicated to man in the form of an acute infection, would not present the same degree of development, and to the same extent in the various organs, which it attains to in the course of several years within the body of the ox or cow. But slight indications may be sufficient for the purpose of identification, provided the indications be true ones. Now, on that point we have the excellent authority of Gerlach. Referring to the fringes of filamentous excrescences that were found growing from the thin margin of the lung in two of the animals experimented on, he observes—"But *most especially are we reminded of Perlsucht* by the growths on the pleura, round the sharp margin of the lung, in the twelfth and fourteenth experiments; *they demonstrate to us the beginnings of Perlsucht.*"

This statement, coming from a competent veterinary pathologist, may be accepted implicitly. It may be added that Orth also found, in the animals which he succeeded in infecting from tuberculous cows, that the pleural new formation occurred chiefly on the margin of the lung.[1]

The large flat tubercles that occurred in Cases 2, 5, and 10, are mentioned in works on human pathology; Virchow, however, states that the size and tendency to become pedunculated (another author, Perls, includes their flatness), should distinguish the nodules of Perlsucht from other tubercles of the serous membranes. I have not found any reference, in human pathology, to the earlier condition of the serous-membrane outgrowths, with which I have chiefly occupied attention in this section. Their undeveloped state is not against them as valuable diagnostic marks, and there is no doubt that they do grow to be the nodules, and the conglomerates of nodules, that are admittedly characteristic of the disease. I have provided two plates of accurate coloured drawings, showing a considerable variety of the appearances that these serous-membrane outgrowths present. I believe that a case of bovine tuberculosis in man may sometimes be detected by these curious formations alone, and I have been at some pains to have the appearances that I believe to be characteristic accurately produced in colours, for the easier detection of future cases and the further elucidation of the subject.

I defer noticing the microscopic structure of the serous-membrane nodules to a later section.

VI.—The Disease in the Lungs. (Plates III.–VI.)

In the twelve cases in man, the nodules and cavities in the lungs divide themselves, in the first instance, into two main classes; one of the classes is represented by the formations in a single case only (Case 7), the other class comprising those of the remaining eleven. The nodules in Case 7 are clearly distinguished by their brownish-yellow colour, their hardness or toughness, their definite round or oval shape, and their thick capsule of translucent tissue (fig. 8, Plate III.); the cavities in

[1] Orth, "Experimentelle Untersuchungen über Fütterungs-Tuberculose."—Virchow's *Archiv*, vol. lxxvi. (1879) p. 229.

the same case are distinguished by their dense fibrous and semi-cartilaginous walls and their granulation-like interior. In the more decided of the other eleven cases, the nodules in the lungs are remarkable for their medullary softness and greyish-white colour, for their tendency to central excavation, and for the want of a regular periphery and the absence of anything like a capsule; the cavities, in like manner, are obviously the softened interiors of nodules, or conglomerates of nodules; their walls are sometimes uneven or ragged, and sometimes smooth, and their contents are whitish, milky or creamy, and of muco-purulent consistence. The difference between the two classes of cases is nothing more than the difference between a chronic case and a preponderating number of acute cases. The cases that most nearly represent an intermediate class are Cases 5 and 6, where the condition of the lung was the very significant crumpet-like condition of fig. 9, Plate III.; the round vomicæ, with smooth thick walls, appear to be the round encapsuled nodules of Case 7, with the central substance removed. A partial exception to the morbid appearances in the class of acute cases should also be made for Cases 9 and 10; these were the only two cases in which the lungs were filled throughout with minute translucent grey tubercles. The infection, when it reaches the lungs, appears, for the most part, to run an acute course, and to be the immediate cause of death. But evidences of an acute process of infection in the lungs may coexist with more chronic indications of the disease elsewhere, as on the serous membranes (Cases 2 and 5), or in the lymphatic glands (Case 5). Also, Case 10 may be taken as showing that an acute infection of the lungs, viz., with minute grey translucent tubercles, may be added to the traces of more chronic disease in the same organ, viz., the remarkable solitary wedge-shaped mass, which had a yellowish-brown colour and toughness of texture exactly corresponding to the chronic nodules of fig. 9, Plate III., which I take as the sole representative of the chronic class. The tubercles of the serous membranes in the same case (Case 10) were evidently of some standing, and it is an interesting fact in the case, that the patient had been in the hospital six months before for "typhoid fever;" it may be assumed that something had occurred in the interval to reawaken or intensify the disease

in the form of the miliary or sub-miliary tuberculosis in the lungs, of which the patient died. In this case (Case 10) the interest centres rather in the healed ulcers of the ileum, and I shall practically disregard the tuberculosis in the lungs, and take the case in a separate section along with the two cases that have the intestinal lesion. The other case, with miliary or sub-miliary tuberculosis of the lungs (Case 9), has afforded what I consider the most typical form of serous outgrowths, but it is otherwise placed in a special category owing to the co-existence of a "scrofulous" ovary, and enormously enlarged and calcareous or petrified mesenteric glands.

With these partial exceptions, the twelve cases divide themselves, in respect of the condition of the lungs, into two main classes, one of them containing a preponderating number of cases of acute lung disease, and the other a single case of chronic or long-standing pulmonary infection. The chronic condition joins on to the acute condition in the most interesting way; and within the more diversified acute class itself, the diversities are only such as mutually explain each other. Taking, first, the latter class of morbid appearances in the lungs, their most general character is the *medullary or greyish-white substance* composing the nodules. In Cases 1 and 2, it was certainly a doubtful point, during the *post-mortem* examination, whether the masses in the lungs, mostly on the periphery and sometimes wedge-shaped, were not secondary tumours, sarcomatous or other. Greyish-white, like the white marble of an old building, was also the colour of the nodules in the other cases, and the medullary softness was generally associated with it. It would be quite misleading to speak of the substance in the lungs as "caseous" in any one of the cases.

The next salient feature of the pulmonary new formation is *the large size of the nodules.* The largest masses were those that could be felt distinctly isolated, with compressible lung substance round about them, as in Cases 1 and 2, and also in Cases 11 and 12; such large masses were usually in the periphery of the lung, and they had sometimes the unmistakable wedge-shape of an embolic infarct; it happened in three cases that one of the lungs contained only one or two such masses, their presence being detected by feeling the lung all over. Fig. 7, Plate III.,

is a coloured drawing of one of them (from Case 2). The mass occurred on the posterior thick border of the lung, in the lower lobe close to the great interlobar fissure. It was distinctly wedge-shaped, with the broad end on the pleura, and a branch of the pulmonary artery nearly as large as a goose quill was traced until it disappeared as if to one side of or beneath the thin end of the wedge. The colour of the mass, when newly incised, was a purer white than it appears to be in the drawing, which was made after the lung had been for some time in spirit. The upper lobe of the lung was of a bright rose-red colour, and perfectly healthy; the lower lobe, in which the mass was situated, differed chiefly in being somewhat more congested, and in having some portion of the base carnified. The cut surface of the wedge-shaped mass showed it to be made up of the confluence or conglomeration of a number of round nodules, which were themselves nearly as large as peas (see Drawing). But when a portion of the tissue (from the other half of the wedge, which had been preserved in potassium bichromate and afterwards in spirit and water, and pure spirit) was examined in microscopic sections, the nodules of the size of peas were found to be not the ultimate unit of the nodular formation, but to be themselves made up of a large number of minute round nodules. The appearance under the microscope of a group of the small nodules is given in fig. 11, Plate IV., and a single nodule is shown in fig. 12 in the same plate. It may be said that the whitish masses in the lungs varied in size from a walnut down to a lentil or even a smaller object, but that, whatever their size as naked-eye tubercles, they all proved to be *conglomerates of smaller tubercles.*

The most significant fact in the agglomeration of a number of small tubercles to form larger masses, is that the latter not unfrequently occurred on the periphery of the lungs in *the shape of a wedge.* Wedge-shaped masses of whitish medullary substance occurred in the lungs in Cases 1, 2, 3, and 12, and in the last case there was also a very well-marked large wedge of consolidation that resembled the grey hepatisation of pneumonia. In Case 10, the most definitely bounded and the sharpest of all the wedges occurred, but it was of brownish-yellow colour, and of hard or tough consistence. These masses had precisely the

form of embolic infarcts, and in the case from which fig. 7, Plate III. is taken, a branch of pulmonary artery led up to and disappeared beneath the thin end of the wedge. Perhaps all that one may infer from this is that the conglomerate of tubercles corresponds to the territory supplied by a terminal branch of the pulmonary artery. The artery may have been blocked by an actual embolus, and an embolus charged with specific properties would perhaps be capable, in some unknown manner, of setting up the corresponding kind of interstitial new growth at a number of points within the vascular area. At all events, in Case 2, from which the coloured drawing is taken, there was embolism also of the middle cerebral artery, and a distinct patch of yellow softening round about the blocked artery; a microscopic examination of which brought out nothing that one could lay hold upon for the theory of specific infection. The doctrine of Waldenburg might be applied to explain both the wedge-shaped masses and the much more common rounded masses of various sizes as due to embolisms. However that may be, there can hardly be any doubt that the new formation is in all cases intimately associated with the distribution of the pulmonary artery.

We come next to certain points of *microscopic structure*. Figs. 11 and 12, Plate IV., are from the other half of the wedge-shaped mass drawn in fig. 7, Plate III., and fig. 13, Plate V., is from the wedge-shaped mass in Case 3 (tuberculosis in a child). Figs. 12 and 13, from different cases, show one of the most remarkable, and perhaps also one of the most characteristic microscopic appearances of the disease. The small nodule or ultimate tubercle is *surrounded by an extensive wreath or zone of vessels*, which, in the preparation, are so distended with blood corpuscles, that they stand out very conspicuously. The vessels are of considerable size, but they have always the structure of capillaries or of small veins. They are apparently tortuous, and they seem to form a kind of plexus round the tubercle. It is only on the periphery of the tubercle-conglomerate that small tubercles so distinctly isolated and so completely invested with blood-vessels are found; in the preparation that fig. 12 is taken from, there are a considerable number of them, forming the periphery of the larger mass. Not

only is the small tubercle surrounded by a coat or capsule of blood-vessels, but branches of blood-vessels sometimes penetrate its interior. In fig. 12 a blood-vessel may be seen running right through the substance of the tubercle; in one of the tubercles of fig. 11, also, there are indications of blood-vessels in the very heart of the nodule. It is the exception to find vessels going through and through the tubercles; but their outer zone commonly shows traces of them. Wherever vessels exist in a tubercle, there the new formation is vigorous; and in the stained preparations, the cells are deeply coloured. The marginal zone of the tubercle, to a greater or less breadth, is nearly always made up of such deeply-stained and well-preserved elements, but the non-vascularised centre has undergone a more or less complete necrosis.

The central necrosis of the small tubercle is well seen in the preparation from which fig. 11 is taken. In two of the tubercles there is an extensive necrotic area in the centre, and the necrotic centre has separated from the vigorous periphery by a crack or fissure running round in a somewhat uniform line. This *clean separation of the necrosed centre from the vascular periphery* is an important point in the pathology of the disease. It applies in the first instance to the ultimate small tubercles that make up the conglomerate, but it applies also to the large or conglomerate tubercles as a whole. The explanation of the central softening of the larger masses appears to be, that it is only such of the ultimate tubercles as lie around *their* margins that have the most perfect vascular coat or capsule, as in fig. 12. They form the ultimate effective barrier or resistance to the spreading necrosis, while the more centrally situated tubercles of the conglomerate have united their severally softened interiors, and have so formed one large central cavity.

The central softening of the larger or conglomerate tubercles is one of the commonest appearances in the series of cases. It is found equally in the larger walnut-sized conglomerates and in the masses of the size of a hazel-nut or pea or lentil. In the former, it amounts simply to an irregular breaking down of the medullary substance; in the latter it gives rise to more definite appearances, more useful for diagnosis. It was remarked in the smaller nodules in Case 2 and in the pre-

vailing kind of nodules in Case 3, as the cases occurred one after the other, that the whitish masses in the lung were as if perforated with a more or less even round aperture, giving an apperance in cross section that might be roughly compared to the broken stem of a clay pipe; so much did the central aperture look like the lumen of an actual tube, that it was for the moment a question whether the whitish periphery of the nodule was not a formation round the wall of small branches of the pulmonary artery. The same characteristic appearance was found throughout the whole of the lungs in Case 8. In Cases 5 and 6, and again in Cases 11 and 12, that condition was found to some extent (and in one of the latter it was remarked in the *post-mortem* room that whitish cylinders like small worms could be made to issue from the centres of the nodules on pressure); but more usually in these cases, the nodules on section showed the appearance of a partly scooped-out hemisphere, the interior being either smooth or slightly ragged. The best examples of the smooth-walled cavities occurred in Cases 5 and 6, in the apex of the left lung in each case; it is the appearance represented in the coloured drawing, fig. 9, Plate III. *The walls of the cavities are so smooth that they have sometimes been taken for portions of dilated bronchi.*

The condition of lung shown in fig. 9 is, I believe, characteristic of the bovine disease. It is the condition to which Trasbot has specially called attention as occurring in the lungs of tuberculous cows and oxen. I have already quoted a summary of his views; the nodules are nourished exclusively at the periphery, vessels are more numerous in the tissue around the nodules, and in the septa or interstices of the large masses of tubercle than in the healthy connective tissue; there the vascularity is often so great as to be mistaken for inflammation; softening begins at the centre and extends towards the circumference of the tubercle-conglomerate, until there remains nothing but the surrounding connective tissue, and its appearance would lead superficial observers to think that it was encysted. It is perhaps worth mentioning, that I had already arrived at a similar explanation of the appearance of the vomicæ of fig. 9 (after mistaking it for bronchiectasis), and had published it in my preliminary notice, before I became acquainted with Trasbot's explanation of the

condition as found in the lungs of bovine animals. The explanation in both cases is briefly, that the periphery of the nodule is well-vascularised, and resists the necrosis which befalls the interior of it, and that the clear separation of the necrosed centre from the vascular periphery gives to the latter the appearance of a smooth wall. That clean separation is shown in two of the small tubercles of fig. 11, Plate IV.

It is the *vascularity of the periphery of the nodule* that accounts for most of the distinctive appearances of the new formations of the bovine disease, not only in the lungs, but also in the lymphatic glands, in the liver and spleen, and to some extent also of those upon the serous membranes. The appearance of nodules as if encapsuled, which was so marked a feature in Case 7 (fig. 8, Plate IV.), depends on the translucency and vascularity of the periphery of the nodules. The same appearance was distinctly seen in the nodules of the liver and spleen in Case 5; and I have already quoted from Walley to the effect that such is also the appearance of the tubercles in the liver of bovine animals. Again, nothing can be more striking than the complete isolation and sharp definition of a number of round nodules, as large as peas, within the lymphatic glands of the same case (see fig. 10, Plate III.). This peripheral vascularity, then, tends in some cases (chronic) to the appearance of *nodules as if encapsuled;* in other cases it gives rise to *smooth-walled cavities* of various sizes, the "closed vomicæ" of veterinary authors (Fleming); and we refer to it also by contrast all the intermediate degrees of *central softening.*

The vascularity of the periphery of tuberculous nodules is only the most lasting manifestation of a tendency towards vascularisation which shows itself elsewhere in the new formation. It is because the new formation of bovine tuberculosis is so well vascularised that it has *affinities* (pointed out by Virchow) *to lympho-sarcoma.* The abundant blood-supply of the tissue is also seen in the walls of cavities such as those of Case 7; the interior of the cavities might be said to have had the look of being covered with granulations, and the microscopic sections of the dense tissue forming the wall were quite like granulation tissue both as regards the lymphoid and spindle-shaped cells, and also as regards the parallel vessels ending on the surface in loops.

But we are never permitted to lose sight of the *imperfect vascularity* of this new formation; and the best index of its imperfect vascularity is the constant occurrence of *giant-cells*.

Giant-cells occur in large numbers in the new formations in all situations,—in the nodules on the serous membranes, in the nodules in the lymphatic glands, in the masses in the lungs, and in the more occasional tubercles elsewhere. They are often of very great size, and they may contain an enormous number of nuclei; the nuclei, when most numerous, are usually ranged round the margin of the cells, and are often elongated or rod-shaped. Examples of giant-cells with marginal nuclei are drawn (under a low power) in fig. 11, Plate IV., from the lung nodules, and in fig. 14, Plate V., from those of a lymphatic gland. A somewhat different variety of them, the kind that usually occurs in the tubercles of the serous membranes, is shown in fig. 15, Plate VI. The central part of the tubercle, in the latter case, is made up of multinuclear cells of various sizes, lying somewhat loosely together; they are evidently derived from the cells that are found in their earlier state in the more peripheral parts of the tubercle, and these latter are simply the pre-existing cells of the ground-substance, or the connective-tissue cells of the part, that have acquired a certain investment of protoplasm round the nucleus, and thereby a certain resemblance to epithelial cells. The close-set margin of nuclei in the giant-cell is the highest development that it reaches as a giant-cell; by developing further in the same direction it becomes a *portion of a blood-vessel*. The giant-cells with margin of nuclei and with protoplasmic centre are usually found in tubercles just internal to the zone of blood-vessels, or between the vascular periphery and the necrotic centre. The blood-vessels are, generally speaking, new formations, as in granulation tissue, and the giant-cells are, as it were, the imperfect developments of them extending more into the interior of the nodules, and they are the signs of failure in the complete vascularisation of the new-formed tissue.

That view of the office and significance of giant-cells in tuberculosis is held by Brodowski, Ziegler, Malassez, Charcot, and others. In former papers, I showed that the formative processes in the placenta afford us an exact physiological type or

paradigm for the giant-cells of tubercles.[1] The formative process in the placenta is largely that of new blood-vessels and blood-sinuses, and there is no mistaking the part that giant-cells play in that process. They are found chiefly in the deeper strata of the new formation (circular muscular coat of the uterus in the Guinea-pig), and in those deeper strata the vascularisation appears to proceed more sluggishly or under greater difficulties than in the surface layers of the decidua. Multinuclear tracts or blocks of tissue, and clusters of smaller multinuclear cells, can be seen co-operating in various ways towards the formation of new blood-channels. The range of variety in the deeper layers of the placenta covers all the modifications of giant-cells that are found in tubercles, and affords, in fact, a perfect physiological type for the latter. The giant-cells of tubercles have no specific significance, other than that they indicate the imperfect vascularity or difficult vascularisation of the new growth. I have placed side by side in Plate VI. a drawing of one of the centres of new formation in the floor of the healed ulcer of the ileum in Case 10, and a drawing of a group of cells in the deepest layer of the Guinea-pig's placenta. In neither case do the cells show any approach to a true vaso-formative function, but in both cases they show remotely or in a feeble degree that tendency to the formation of new blood-vessels which the placenta shows to perfection in its more superficial layers, and the tubercle shows in its periphery. This brings us to the consideration of the questions in what sense giant-cells are characteristic of the specific bovine disease.

[1] Creighton, (1.) "On the Formation of the Placenta in the Guinea-pig," *Journal of Anatomy and Physiology*, vol. xii. (1878). (2.) "Further Observations on the Formation of the Placenta in the Guinea-pig." (3.) "The Physiological Type of the Giant-cells of Tubercles and Granulations," *Ibid.*, vol. xiii. (1879).

(*To be continued.*)

EXPLANATION OF PLATES I. TO VI.

PLATE I.

Fig. 1. Concave base of *lung* and adjoining convex lateral aspect, covered with leaf-like or cord-like pleural outgrowths; margin of the lung, showing a border or frill of the same. From Case 9.

Fig. 2. Upper surface of the *liver*, showing patches of delicate membrane-like outgrowths, with free and sometimes upturned edges; they are formed by the coalescence of the smaller kind of outgrowths of fig. 1. From Case 9.

PLATE II.

Fig. 3. Under surface of *diaphragm*, covered with an eruption of large flat nodules, for the most part uniform in size, sometimes confluent; membranous appearance at lower part of the figure. From Case 2.

Fig. 4. Sharp margin of lower lobe of *lung*, showing characteristic pleural outgrowths. From Case 7. (The brown colour of the lung substance is owing to its having been preserved for a time in potassium bichromate).

Fig. 5. Lateral convex surface of *lung*, showing sessile and pedunculated pleural outgrowths, of various sizes and of whitish colour. From Case 3. (Typical acute tuberculosis in a child).

Fig. 6. Surface of *spleen*, showing sessile, pedunculated, and tongue-shaped outgrowths of the peritoneal covering. From Case 5.

PLATE III.

Fig. 7. *Lung*, with whitish wedge-shaped mass near interlobar fissure; the mass is dimly seen to consist of a number of confluent round nodules; a branch of the pulmonary artery runs up to and disappears beneath the thin end of the wedge. The interlobar fissure is bridged over by pleuritic membrane. From Case 2. (Spirit preparation).

Fig. 8. Piece of *lung*, with membranous expansion of pleura on right-hand edge, and the substance occupied by a number of yellowish-brown nodules definitely encapsuled by translucent tissue. From Case 7. (Bichromate of potash preparation).

Fig. 9. Piece of *lung*, showing a number of smooth-walled cavities of various sizes and shapes; whitish nodules in the intervening lung substance. From Case 5. (Bichromate of potash preparation.)

Fig. 10. Section of bronchial *lymphatic gland*, showing a number of round nodules in its interior, each definitely bounded by a translucent capsule. From Case 5. (Bichromate of potash preparation).

Plate IV.

Fig. 11. From the wedge-shaped mass in the *lung* in fig. 7 (Case 2); four of the small tubercles that make up the conglomerate; partial vascularisation of the new growth; separation of the necrosed centre from the vascularised periphery. (× about 60.)

Fig. 12. From the edge of the wedge-shaped mass in the lung in fig. 7 (Case 2); a single ultimate tubercle, partly vascularised in its interior, and with an extensive investment of tortuous blood-vessels on its periphery. (× about 150.)

Plate V.

Fig. 13. From the wedge-shaped mass of whitish substance in the *lung* in Case 3 (typical acute tuberculosis in a child); a single tubercle surrounded by an extensive plexus of distended blood-vessels. (× about 60.)

Fig. 14. From a bronchial *lymphatic gland* in Case 5; several tubercles occupying the follicular tissue; the cortical lymph sinus contains red blood-corpuscles; the tubercles contain giant-cells, and are partly necrosed or calcified. (× about 60.)

Plate VI.

Fig. 15. From thickened floor of healed *ulcer in the ileum* in Case 10; a tubercle with multinuclear cells lying loosely in the centre, and epithelial-like cells in the periphery; transition of the connective-tissue cells of the region to become the epithelial-like cells. (× 250.)

Fig. 16. Similar appearance to that of fig. 15, from the *normal placenta* of the Guinea-pig; transition of the enlarged and epithelial-like cells of the circular muscular coat to become multinuclear cells. × 150.

Fig. 17. Appearance found near one of the small scattered nodules in the lower lobe of the *lung* in Case 7; the bronchial wall broken through, and the lumen of the tube filled up by a portion of the tubercle. (× 90.)

ON TERTI ITAL CONDYLE. By WILLIAM ALLEN, *)emonstrator of Anatomy, University of Glasgow.* (PLATE VII.)

IN the osteological collection of the Anatomical Museum of this University there is a skull of an adult female, which presents the peculiarity of having, in addition to the normal articular surfaces for the atlas, a third occipital condyle which lies between the anterior extremities of the other two.

This tertiary condyle is in the form of a conical process of bone, about two-fifths of an inch in depth, directed downwards from the anterior edge of the *foramen magnum*, and bearing posteriorly a vertical transversely concave articular surface, which extends superiorly to the upper level of the basilar process.

On making further search through the same collection, I succeeded in finding two other skulls which presented the same abnormality, but to such a trifling extent as to be easily overlooked, unless when specially sought for. One of the skulls is that of an aged male, the other belongs to a five months' fœtus. In the old skull the abnormal condyle is simply a small facet on the middle of the posterior edge of the *basi-occipital;* in the young skull the articular surface extends right across the whole width of that edge, and is in shape somewhat like the lesser sigmoid cavity of the ulna.

In Professor Allen Thomson's collection of crania in the Hunterian Museum the same articular appearance exists in the skull of a native Australian; but neither in this case, nor in the other two, does the condyle form any projection inferiorly, nor is it so well developed as in that which first attracted my attention. In all, however, the facet is so placed as to suggest that it articulated with the odontoid process.

Meckel[1] seems to have been the first to place on record a case of tertiary occipital condyle; but judging from the drawing which he gives of the case, the condyle appears to have been on the

[1] "Ueber einige Abnormitäten der Knochen."—*Deutsches Archiv. für die Physiologie*, vol. i. p. 644, and Taf. vi. fig. 37.

under surface of the *basi-occipital*, and was in all probability due to contact with the anterior atlantal arch.[1] His case, therefore, is very different from the above, in a morphological sense, and is probably analogous to what is sometimes seen in other mammals, where the groove on the under part of the *basi-occipital*, against which the anterior arch of the atlas is pressed in flexion, becomes to a slight extent articular.

Other articular facets occasionally appear in the neighbourhood of the *foramen magnum*. Their most frequent site is at the posterior edge of that opening, but sometimes they may be found on the under part of the *processus jugularis*.[2] They are usually named pressure facets, and are only mentioned here in order to be discriminated from the foregoing.

Many interesting points arise in connection with the occasional presence of a tertiary occipital condyle in man. Principal amongst them is the fact that it demonstrates an unbroken series of centra in the vertebral and cranial segments, the structure of the abnormal joint being also suggestive of the correctness of Luschka's statement as to the synovial character of the middle portions of the intervertebral discs with which it is in serial continuity.[3] In addition to this it illustrates very prettily the connection which exists between the occipito-vertebral articulation of mammals and other vertebrata, and serves also to elucidate the nature of the anterior portions of the normal mammalian condyles.

With the exception of amphibians, the cranio-vertebral articulation of the lower vertebrata is perfectly homologous with the articulations between the bodies of their vertebræ. In the single condyle of the crocodile or turtle there are distinguishable

[1] See fig. 3, which is an example of this spurious tertiary condyle.

[2] A good example of supernumerary articular surfaces on the occipital exists in a skull presented to the Hunterian Museum of this College by Dr Rankine of Carluke, and described by him in *Edin. Monthly Jour. of Med. Science*, 1848, p. 1071. Facets exist on the under surface of each jugular process, and it is probable that they articulated with the transverse processes of the atlas. The case is an approach to one which I described and figured in this *Journal* (Oct. 1879, Plate II. fig. 5), in which the left atlantal transverse process is joined to the superimposed jugular process by a vertical rounded pillar of bone, which bears evidence of having been at one time formed from two parts, which articulated but afterwards fused, the same fusion existing at the normal occipito-atlantal articulation.

[3] Luschka, *Die Halbgelenke des Menschlichen Körpers*, Berlin, 1858, p. 84.

three factors, a central and two lateral, and in each of their vertebral bodies the same three factors also exist. In the mammalia the vertebral bodies are similarly made up, and the three factors can be easily distinguished in the young state, but, at the junction of cranium with spine, this simple intervertebral character of the articulation is lost, and the question may then be asked, Are the two occipital condyles of mammals equivalent to the three factors of which a vertebral body is composed, or to the two lateral elements only? That the mammalian atlanto-occipital articulations correspond to the articulations between the lateral parts of the bodies of the adjacent vertebræ has been already pointed out;[1] but that they correspond to something more is made apparent by examination of the occipital condyles of the human subject in the condition presented by them in early life. The major part of each condyle is then seen to lie on the *ex-occipital,* a small anterior portion encroaching on the adjacent part of the *basi-occipital.* The part formed by the ex-occipital is the complete homologue of the articulations of the lateral parts of the bodies of the vertebræ with one another, but the part on the *basi-occipital* is not in serial continuity with those articulations. Thus the inquiry gets limited to the question, Are the small anterior ends of the condyles the divided parts of an intervertebral surface of the *basi-occipital?* By reference to the case under consideration, we are led to believe that they do not correspond to that portion of the occipital centrum, but are merely adventitious, as is proved by the fact that in normal cases these angular facets come in contact with the superior surface of the extremities of the anterior arch of the atlas, a part morphologically anterior to the chain of vertebral centra.

Comparison with the superior articulating surfaces of the young axis brings out this point even more forcibly; just as in the case of the occipital condyles in the young state, each articular surface is spread over two parts, an outer, the larger, lying on the lateral mass, and an inner adventitious smaller part lying on the projecting side of the base of the odontoid process. These articular angles on the base of the odontoid correspond to the facets on the angles of the *basi-occipital,* just as the surfaces

[1] Cleland, "On the Serial Homologies of the Articular Surfaces of the Mammalian Axis, Atlas, and Occipital Bone."—*Nat. Hist. Rev.* April 1861.

of contact of the centra of the atlas and axis correspond to the articulation of the tertiary condyle with the summit of the odontoid.

It remains to determine with what other changes the occasional presence of a tertiary occipital condyle is associated. That the changes are not cranial is to be inferred from the fact that in each of the dry specimens examined the proportions of the different parts to one another are normal. Perhaps objection might be taken to this statement, as in the principal specimen, the basilar process of the occipital forms a projection downwards, but this is shown by comparison with the other specimens (in each of which only a facet exists on the *basi-occipital*) to be a secondary formation. We are led to conjecture, therefore, that the changes in these cases are vertebral, no doubt the principal one being growth upwards of the odontoid process.

This theory I have had the satisfaction of proving quite recently by the accidental discovery of another case of tertiary condyle, when making a vertical section through the skull and vertebral column of a fully-matured fœtus. The odontoid process is in this case greatly increased in length, and is elevated considerably above the edge of the atlantal arch. It articulates as usual with the arch of the atlas, which is perfectly formed; but above this articulation there is a second, in which an obliquely-shaped facet on the front of the summit of the odontoid comes in contact with the middle of the posterior edge of the *basi-occipital*. Having taken for comparison a fœtus of the same size, in which a similar section had been made, it was then found that in the normal specimen the odontoid process exceeds the depth of the axial centrum by one half, and its summit is only very slightly higher than the upper edge of the atlantal arch. In the abnormal specimen, on the other hand, the odontoid is exactly twice the depth of the axial centrum,[1] and although the atlantal arch seems to be deeper than usual, the summit of the odontoid reaches considerably higher up. When examined more closely the abnormal odontoid has a larger facet for the atlantal arch than that which is usually seen at that age; taking this facet as the centre of the anterior surface,

[1] The axial centra, as well as the centra of the lower cervical vertebræ, are in both subjects equal in depth.

the increased growth of the odontoid is seen to have been due to additions at both of its extremities, for the depth from the inferior edge of the atlantal articular facet to the inferior surface of the odontoid, as well as that from the summit of the odontoid to the upper part of the same articular facet, measures in each case more than the corresponding parts of the normal specimen. The abnormal articulation is slightly smaller than that between the odontoid and the arch of the atlas, and is lined by a prolongation of the same synovial membrane. The section brings out other interesting points. The *basi-occipital* is nearly in the same straight line as the axis of the vertebral column, the head being in a position of over-extension. As the result of this abnormal position of the head, the posterior arch of the altas is raised up in front of the posterior edge of the *foramen magnum*, and has the *dura mater* tightly stretched over it, forming part of the floor of the posterior fossa of the cranium. There is also a close approximation of the spines of the cervical vertebræ, that of the axis in particular being closely pressed against the under part of the posterior atlantal arch. The atlas is perfectly formed, the only difference between it and the normal is a slight increase of its transverse measurement at the expense of its antero-posterior diameter, and as a result of this increased width, the lateral masses of the atlas are supported by the corresponding parts of the axis only, the angles of the base of the odontoid not having entered into the formation of the axial superior articular surfaces. Of all the variations in this case, the most important is the great elongation of the odontoid, a remarkable feature in connection with which is that the increased growth is due to additions made at both ends, and not solely to its summit.

It may be asked, Can this great elongation of the odontoid be accounted for? In the consideration of this question the co-existing peculiarities of the case are to be taken into account. Eliminating the abnormal articulation, which is simply the result of the elongation of the odontoid process, the other changes already mentioned are—over-extension of the head, diminution of cranio-vertebral curvature, and a slight separation of the lateral masses of the atlas. By over-extending the head in the normal specimen, the following effects ensue—the

posterior edge of the *basi-occipital* is brought directly over the summit of the odontoid, although the distance between them is not diminished; the occipito-axial ligament (*apparatus ligamentosus*) is relaxed, so that in this position it does not bind down the summit of the odontoid; finally, a separation of the atlantal masses is produced, and, as hinted at, this prevents them from articulating with the angles of the base of the odontoid which form the inner moieties of the superior articulating surfaces of the axis, so that pressure is not transmitted to the base of the odontoid from the head. Under these circumstances, the odontoid is relieved from all longitudinal pressure. The result of this remains to be seen.

I have described elsewhere [1] a specimen which seems to throw some light on the present inquiry. The specimen consists of the bones of an arm, obtained from a subject dissected in the Rooms, and there are exhibited by it curious anatomical changes due to a dislocation backwards of the head of the radius in early life. The head of the radius is not in contact with either the capitellum or the lesser sigmoid cavity, but is placed behind the external condyle of the humerus, and has grown upwards to be almost as long as the ulna, the increase being chiefly in the neck, which is twice as long as usual. In addition to this the outer condyle of the humerus has grown downwards below the level of the inferior surface of the internal condyle to the extent of three-quarters of an inch, and it has been found by careful measurement that there is represented in the outer part of the diaphysis of the bone increased longitudinal growth half an inch in extent. Judging from what is so apparent in this case, it becomes obvious that in the analogous case of the odontoid growth to the abnormal extent represented was due to the removal of pressure at an early date in the manner above pointed out, and then the edge of the basi-occipital being placed by the same movement directly above the summit of the odontoid, the two parts came together and formed the abnormal articulation.

The analogy between the two cases seems to be more complete, for at the upper end of the spine of this fœtus there is

[1] *Glasgow Medical Journal*, July 1880, "On the Anat. Changes induced at the Elbow by luxation backwards of the head of the Radius in early life."

detectable an approach to what has been described[1] as a variety of congenital luxation of the atlas, to which there seems to be a predisposition from the shape of its lateral masses and adjacent hard parts. The mechanism by which the luxation can be produced is seen by making a transverse vertical section down through the occipital condyles and vertebral column. The atlantal lateral masses appear in the section as two horizontal wedges, the thin edge of each being internal; fitting in between them superiorly there is a vertical wedge formed by the everted occipital condyles, and fitting in between their inferior surfaces there is another vertical wedge, but inverted; it is formed by the everted superior articular surfaces of the axis. (See fig. vi.)

Increased pressure transmitted longitudinally through the fœtus would therefore have a tendency, on account of this wedge-like mechanism, to force the lateral masses of the atlas outwards. Ordinarily this is obviated by the tension of the atlantal arches and transverse ligament, and also it may be assumed that in the normal flexed position of the fœtus *in utero* all the pressures on the head are not transmitted through the atlanto-occipital articulation, some probably passing down through the sternum, against which the chin is so firmly pressed, so that this mechanical arrangement does not act injuriously. It may occasionally happen, however, that this wedged-shaped mechanism comes into action; for, by extension of the fœtal head *in utero*, which can be explained by spasm of fœtal muscles,[2] the superior vertical wedge is increased on account of the rolling forwards of the condyles, and at the same time all the pressures on the vertex are transmitted through the occipito-vertebral articulation; there is thus increased power acting at a great mechanical advantage. As a consequence, displacement of the lateral masses of the atlas occurs; if slight, the posterior arch of the atlas is only straightened; if greater, the arch gives way, but as the transverse ligament keeps the front parts of the masses together, their hinder ends move outwards and forwards.[3]

[1] Guérin, in *Gazette Medicale*, 1851, p. 227.

[2] Guérin considers that all congenital dislocations are due to an active contraction of the muscles of the fœtus, the remote cause of which is to be looked for in the affection of some part of the central nervous system.—"Recherches sur les luxations congenitales."—*Gazette Medicale*, 1841, No. 7, 10.

[3] An altas which I described and figured in this Journal (*loc. cit.*, fig. 8) may be

In either case, the base of the odontoid is relieved from pressure, so that abnormal growth might result; but if the separation is greater still, increased growth of the odontoid does not follow, as the occipital condyles would then come in contact with the inner parts of the axial surfaces, and they would therefore have to bear as much pressure as before.[1]

Only the minimum effect occurred in the case of the fœtus under consideration; for although the head is over-extended (and was probably in such a position *in utero*), and, at the same time, the occipital condyles are very prominent, still the lateral masses are only slightly separated, as the posterior atlantal arch was of sufficient strength to remain unruptured, and is only somewhat straightened out.[2]

To briefly summarise, the important points brought forward in the above communication are—

(*a.*) The third occipital condyle which is occasionally seen in the human subject corresponds to the intervertebral surfaces of the vertebral centra, and is also the morphological representative of the central element of the single avian and reptilian condyle.

(*b.*) The abnormal articular surface is associated with growth upwards of the odontoid process, and is not the result of any change beginning primarily in the cranium.

(*c.*) The exaggerated growth of the odontoid is due to its having been at an early date relieved from pressure, this theory being strengthened by a similar growth, consequent on removal of pressure, existing in a case of a different description referred to in the text.

(*d.*) This relief of the odontoid from pressure is consequent on changes induced at the upper end of the vertebral column on account of the fœtal head having been maintained in an over-extended position *in utero.*

taken as a good example of this mode of luxation. Briefly, its peculiarities are—a deficiency in the posterior arch, the anterior arch straightened, and the back parts of the condyles so far separated that the tips of the transverse processes are directed forwards.

[1] A case in which the atlantal masses were so greatly separated, that the occipital condyles came in contact with the axial articular surfaces, is described by Schiffner, and referred to in my former paper (*loc. cit.*).

[2] Guérin (*loc. cit.*) mentions cases of sub-occipital luxation coexisting with an over-extended position of the head.

Explanation of Plate VII.

Fig. 1. Occipital part of the female skull which shows the tertiary condyle described at the commencement of the paper.

Fig. 2. Occipital bone of a five months' fœtus. Besides showing the angular facets on the *basi-occipital*, which form the anterior ends of the normal condyles, there is also seen on the posterior edge of that part a semilunar facet, the tertiary condylè.

Fig. 3. A good example of what may be called spurious tertiary condyle, occurring on the occipital of a young subject. The abnormal facets are placed on the under surface of the *basi-occipital*, and probably came in contact with the anterior atlantal arch.

Fig. 4. The occipital condyle of a chelonian, showing the three elements of which it is composed.

Fig. 5. Vertical section through the vertebral column and skull of a full-term fœtus in which a tertiary condyle exists. There is shown the great elongation of the odontoid and the other peculiarities mentioned in the text.

Fig. 6. Transverse vertical section through occipital condyles, and lateral masses of atlas and axis. The figure is intended to represent the wedge-like mechanism that exists at the upper portion of the vertebral column. The dotted line through the axis represents the line of junction of atlantal and axial centra, and it also shows that the inner parts of the axial superior articular surfaces belong to the atlantal centrum.

ON

ON SOME POINTS [illegible] STOLOGY OF CIRRHOSIS OF THE LIVER.

By J. DRESCHFELD, M.D., M.R.C.P. Lond., *Lecturer on Pathology, Owens College, Manchester.* (PLATE VIII.)

THE important researches of Charcot and Gombault (*Arch. de Phys. norm et path.*, 1876, and Charcot, *Leçons sur les maladies du foie, etc.*, Paris, 1877) have directed the attention of pathologists to certain minute changes associated with different forms of chronic interstitial hepatitis which previous to these researches had received but scanty notice. Charcot and Gombault, basing their observations on the results obtained by ligaturing the common bile duct in animals, and on the microscopic examination of livers affected with ordinary alcoholic cirrhosis and the co-called hypertrophic cirrhosis, and of livers where there had been mechanical obstruction to the biliary passages, have described different forms of cirrhosis, namely—

1. The multilobular, venous or atrophic cirrhosis, which is the ordinary alcoholic cirrhosis, and which is characterised by the deposition of the newly-formed fibrous tissue round the smaller branches of the portal vein. The bands of fibrous tissue surround here several lobules in the form of a ring, though smaller and thinner bands penetrate between the several lobules, hence they have also called it annular cirrhosis.

2. The monolobular or biliary cirrhosis. This form is characterised by the development of fibrous tissue round each lobule. The newly-formed tissue is formed round the interlobular biliary ducts, which themselves are found in a state of proliferation, forming a network of thin-walled canals in the interlobular spaces, and are found filled with cubical epithelium. This form of cirrhosis is found idiopathically as the hypertrophic cirrhosis, a rare disease, described by Cornil, Hayem, and especially by Hanot (*Thesè de Paris*, 1876), and characterised during life by persistent jaundice, persistent enlargement of the liver, and absence of ascites. The histological changes found in this disease are also found in cases of jaundice due to obstruction, and, as was observed

before by Mayer (*Wiener. Med. Jahrb.* 1872, ii.) and Wickham Legg (*St Barth. Hosp. Rep.* vol. ix.), in the livers of animals whose common bile duct had been ligatured during life.

3. The pericellular cirrhosis. In this form the fibrous tissue is found round several cells of one lobule. This form of cirrhosis is chiefly found in cases of congenital syphilis.

We are here concerned with the first two kinds of cirrhosis, which differ, according to Charcot, in these three particulars: the ordinary alcoholic cirrhosis is multilobular, the fibrous tissue develops around the portal venules, and there is no proliferation of biliary ducts; the biliary cirrhosis, on the other hand, is monolobular, the fibrous tissue forms round the biliary ducts, and these are markedly proliferated. Soon after the appearance of M. Charcot's researches, Friedländer (*Über Epithelwucherung und Krebs*, Strassburg, 1867) described marked proliferation of biliary ducts in cases of alcoholic cirrhosis and in cases of syphilitic cirrhosis, while, on the other hand, he missed them in many cases of jaundice due to obstruction. Friedländer believed in all these cases the proliferation to be an atypical development of epithelial cells. Since then some interesting observations on this subject have been published by Brieger (*Virch. Arch.* vol. lxxv. p. 85), and quite recently by Litten (*Charité Annalen*, vol. v. p. 153).

Brieger, examining the liver in early alcoholic cirrhosis and in many other pathological conditions, came to the following conclusions:—

1. In the ordinary form of cirrhosis, besides the new formation of fibrous tissue round the portal vein, there is also new formation of fibrous tissue round the hepatic vein in the form of fine trabeculæ, which, separating the liver cells in rows, pass through the lobule and become connected with the fibrous tissue round the portal vein; and

2. The proliferation of the biliary ducts occurs not only in cases of obstructive jaundice, but also in many other pathological conditions, in which some interstitial hepatitis is found, such as the ordinary alcoholic cirrhosis, the nutmeg liver, the cirrhotic livers from cases of tuberculosis with or without peritonitis, syphilitic hepatitis, and tight-laced liver.

Brieger, like Charcot and like Kiener and Kelsch (*Arch. de*

Phys. norm. et path. 1876, pp. 622 and 771), has traced the proliferation of the ducts quite into the interior of the lobule, and believes that they are formed from atrophic liver cells.

Litten (*loc. cit.*) made cirrhosis from biliary obstruction the subject of an experimental and clinical study, and found on repeating the ligature experiments, that when operating antiseptically he was not always able to produce biliary cirrhosis, and that, on the other hand, irritation of the common bile duct without ligature (by the application of croton oil to the duct) was in itself sufficient to produce proliferation of the biliary canals. From these and other observations on human livers, where there was more or less interstitial hepatitis without stagnation of bile, Litten is inclined to agree with W. Legg in considering the proliferation of the biliary duct secondary to irritation by an inflammatory process affecting the perilobular fibrous tissue.

Litten further observed three cases of mechanical obstruction of the common bile duct, which were followed by distinct atrophic cirrhosis, with all the clinical symptoms, and where after death marked proliferation of the biliary ducts and the changes of atrophic cirrhosis were found, and by the light of these observations disputes the distinction made by Charcot between biliary and portal cirrhosis, at least as far as the biliary cirrhosis due to mechanical obstruction is concerned.

Our knowledge of the histological changes in the atrophic cirrhosis of the liver has recently been enlarged also in another direction. Whilst nearly all former observers have traced the origin of the newly-formed fibrous tissue to embryonic cells in the neighbourhood of the portal blood-vessels, and have considered these embryonic cells to be either emigrated leucocytes or to have developed from tissue corpuscles, Kiener and Kelsch (*Arch. de Phys. norm. et path.* August 1879) and Hamilton (*Journal of Anat. and Phys.* vol. xiv.) have traced the development of the fibrous tissue direct from the hepatic parenchyma. According to Hamilton, there are first changes in the nuclei of the liver cells, leading eventually to proliferation of the liver cells; this stage is followed by the gradual disappearance of the protoplasm from these young cells, leaving nothing but free nuclei which subsequently develop into spindle cells and fibrillæ.

Since the appearance of Professor Charcot's researches, whose beautiful specimens I had an opportunity of seeing, I have carefully examined the liver in many and varied pathological conditions, and though I have at different times made short communications on this subject to the microscopic branch of the Medical Society, I beg now to be allowed, in view of the recent researches quoted above, briefly to review the results of my observations.

These observations were made with the view of elucidating the following three points :—

1. The relation of the multilobular to the monolobular cirrhosis, and the behaviour of the biliary ducts in each of these two forms;

2. The mode in which the proliferation of the biliary ducts takes place; and

3. The origin of the newly-formed fibrous tissue.

As regards the first of these three points, I found on examining cases of alcoholic cirrhosis, that when far advanced they all presented the multilobular character which Charcot describes. Thick bands of fibrous tissue surround several lobules, enclosing the liver perenchyma in the form of the characteristic granules, whilst finer bands pass between the several lobules thus held together. Proliferation of biliary ducts is but rarely seen, and in a very slight degree, and only in connection with the finer bands; in the thicker and coarser bands the biliary ducts are seen unaltered or atrophied or compressed. It is very different, however, in some early cases of alcoholic cirrhosis, where death has taken place after accident or from intercurrent disease, and where the clinical symptoms of the cirrhosis have been either entirely wanting or but little expressed during life. The number of such cases at my disposal has been rather abundant, owing to the numerous deaths due to accident which occur at our Infirmary, and to the excessive spirit-drinking prevalent in our district. The liver in such cases is slightly enlarged, its surface smooth, its consistence firm, though the liver is easily cut, and on section the cut surface has a smooth appearance (owing to the fibrous tissue not having as yet undergone contraction); each lobule is, however, seen to be surrounded by a deeper coloured band of fibrous tissue. Examined with a low power, monolobular

cirrhosis, with marked proliferation of the biliary ducts in the interlobular spaces, is seen. On examination with a higher power, the liver shows changes, some of which are depicted in fig. 1 (kindly drawn for me from the specimen by my friend Dr A. H. Young, pathologist to the Manchester Infirmary), which represents a section of a liver from a patient who died a few days after ligature of the external iliac artery for an arterio-venous aneurism of the femoral artery. The patient had been an excessive spirit drinker, and had suffered from arterio-sclerosis, but he had no symptoms of cirrhosis of the liver during life, and *post-mortem* neither ascites, nor abnormal condition of the abdominal veins, nor an enlarged spleen was found. The liver lobules are seen separated from each other by a quantity of young fibrous tissue, consisting of small round cells, spindle cells, and fibrillæ, the latter being found both near the periphery of the lobule and further off in the centre of the interlobular space; rows of spindle cells and fibrillæ pass into the lobules itself (*a*), often surrounding liver cells in the form of insular bands (*b*). I have, however, not seen them penetrate quite to the central hepatic vein, nor did the latter show any changes in its neighbourhood. Besides these tracts of fibrous tissue, the interlobular spaces showed marked proliferation of very fine biliary ducts, forming a dense network of slender canals filled with epithelial cells, usually arranged in rows of two or four, and passing quite into the lobule (*c*). Their connection with the liver cells, which could be made out in some places without great difficulty, will be described hereafter.

The parenchyma of the lobule itself showed some marked changes, which also will be noticed further on, when considering the third point of our inquiry.

It will thus be seen that in the early form of alcoholic cirrhosis we have a monolobular cirrhosis, with proliferation of biliary ducts. My own observations on this point, which were laid before the Microscopical Society more than two years ago, accord well with those of Brieger (*loc. cit.* p. 92). I have not been able to trace the exact connection between these earlier monolobular and the fully advanced multilobular forms; it is, however, highly probable that, as the interstitial cirrhotic process continues, the proliferation of the biliary ducts ceases, and the

further increase of the fibrous tissue takes place more round the portal veins of large calibre, and thus by the gradual shrinking of the newly-formed fibrous tissue, the annular character of the cirrhosis and the atrophy (and according to some fibrous degeneration) of the biliary ducts seen in mutlilobular cirrhosis would result.

Another exquisite example of monolobular cirrhosis I saw in cases of far-advanced fatty liver. I examined two such cases, where the clinical history and *post-mortem* appearances were almost identical. In both cases the symptoms set in suddenly, and consisted of vomiting, abdominal pain, followed by sudden collapse and death about 48 hours after the first onset of the symptoms. In the first of these two cases (a prostitute addicted to excessive drinking) a coroner's inquest was ordered, and in the second (a middle-aged woman, known to have been an alcoholic), the patient's friends suspecting poisoning, a *post-mortem* was ordered by the husband. In both cases the liver was found in a state of far-advanced fatty infiltration; it was large, pale yellow in appearance, of smooth surface, and looked exactly like livers of geese which are made into patties. On section each lobule was seen to be surrounded by a darker band, and on examining a section under low power, monolobular cirrhosis, with excessive proliferation of biliary ducts, was seen. Fig. 2, for which I am again indebted to my friend Dr Young, represents a section under a high power. The parenchyma of the lobule is seen to be made up mainly of fat cells, and in but few places only can liver cells be discerned flattened and atrophied. At the periphery the liver cells were seen to proliferate and to pass into biliary canals, exactly as in the case of early alcoholic cirrhosis, to be presently described. At the periphery of the lobule also tracts of embryonic fibrous tissue were seen penetrating the lobule from without for a considerable distance. The spaces between the lobules were almost completely made up of nets of biliary ducts, with a sparing quantity of fibrous tissue.

In nutmeg livers, and livers from cases of chronic peritonitis, the appearances are by no means constant, there being sometimes scarcely any interstitial hepatitis, while at other times there is found a large quantity of fibrous tissue round the lobules. I have, however, almost invariably found that in all those cases

where there is a great deal of monolobular interstitial hepatitis, there is also a marked proliferation of biliary ducts.

Coming now to cases of biliary cirrhosis due to mechanical obstruction to the flow of bile, I have examined many livers so affected from the most varied causes. In some of these neither monolobular cirrhosis nor proliferation of biliary ducts was found (notably was this the case in some cases of obstruction due to gall-stones, in a case of pressure caused by an intrahepatic hydatid cyst, and a case of simple inflammatory occlusion of the common bile duct); in others both these changes were well seen (two cases of cancer of gall-bladder with secondary deposits in liver, cases of gallstone, and three cases of cancer of the head of the pancreas obstructing the common bile duct). The absence of the monolobular cirrhosis in some of the cases is not easy to explain; it is certainly not due to the short duration of the obstruction, as some of these cases were jaundiced for months; nor is it likely to be due to a propagation of the inflammatory process from the larger to the smaller ducts, or the irritation set up by such a process, as Litten and Wickham Legg suppose, for I found it wanting in the very case where the common duct was occluded and adherent to the surrounding structures by a simple inflammatory process. As it is only found when there is also interstitial monolobular hepatitis, it is not improbable that it is secondary to this inflammatory process, and might be compared to the proliferation of the alveolar epithelium of the lung in many chronic lung affections, characterised by an increase of the fibrous tissue round the alveoli, and to the alteration in the renal epithelium in cases of interstitial nephritis,—a point to which Professor Charcot in his writings has often drawn attention. From the above observations, I think it would be well to distinguish histologically between the multilobular cirrhosis of the far advanced cases of alcoholic interstitial hepatitis, and monolobular cirrhosis, with its accompanying proliferation of the biliary ducts, though this latter variety has not the etiological and clinical significance which Charcot at first gave to it.

As regards the second of the three points under consideration, I had no great difficulty, especially in the cases of early cirrhosis and of fatty liver, to trace the proliferating biliary canals to the liver cells. The view which I am obliged to take from a study

of the specimens differs materially, at least for some forms, from that expressed by Brieger, who believes that the liver cells become smaller and atrophic, and arrange themselves in longitudinal rows, which by simply leaving a lumen between the rows of cells would form biliary canals. I have noticed in my specimens at first a proliferating process in the liver cells of the peripheric part of the lobule; the nucleus of the liver cells enlarges to a considerable extent and takes the staining better than the nucleus in the ordinary liver cell; then there are seen liver cells with two, four, or even more nuclei; next we have an endogenous cell-growth from these nuclei; liver cells are thus seen, increased in size and longitudinal or oval in shape, filled with small cells, each having a distinct nucleus and a small amount of protoplasm, and resembling in appearance the cubical epithelium found in the nets of new-formed biliary ducts close to the periphery of the lobule; and, lastly, the direct connection of these proliferating cylindrical masses with small biliary ducts, already possessing a lumen, and lined by small epithelial cells, was seen, giving at first sight an appearance as if the biliary ducts terminated in club-shaped blind extremities, as was described by Waldeyer in a case of acute yellow atrophy of the liver. I have no doubt that the formation of biliary ducts by atrophy of the liver cells, described by Brieger and others, also occurs, and indeed in cases of mechanical obstruction to the biliary duct, I have seen an appearance much resembling that described by Brieger. These two modes of formation most likely correspond to two different pathological processes,—in the one case we have to do with active proliferation and new formation of biliary canals, and in the other we have a gradual change of the liver cells into bile ducts, due to atrophy of the cells by compression of the surrounding fibrous tissue.

Thirdly, as regards the development of the fibrous tissue from liver cells, though I saw all the first changes in the liver cells described by Hamilton, I have not been able to satisfy myself as to the eventual conversion of the liver cells into fibrous tissue. The cases of early cirrhosis are here again the most valuable for studying these changes. In the case of which fig. 1 represents a section, the parenchyma of the lobule showed normal liver cells, atrophic cells, and large masses of fat cells throughout the greater

portion of the lobule; at the periphery of the larger lobules, and to a larger extent in the smaller lobules, the liver cells showed the nuclear changes, the proliferation, and the gradual change into biliary canals already described; in other portions of the preparation the proliferating and many nucleated liver cells were seen to form spindle-shaped bands, showing still the component cell elements, but somewhat compressed and elongated. These bands were seen in the circumference of the lobule, and also between tracts of more fully formed fibrous tissue in the interlobular septa; they were surrounded or compressed by fibrous tissue, but I have not been able to trace their conversion into fibrous tissue. On the other hand, even in this early cirrhosis, the demarcation between the embryonic fibrous tissue and the liver parenchyma, except where obscured by the proliferating biliary ducts, was very marked, and tracts of this tissue could be traced close to but still separate from the many nucleated liver cells quite into the lobule; furthermore, masses of embryonic cells were seen immediately around the interlobular vessels, and the tissue here seemed often of younger growth than that nearest the periphery of the lobules, which would not be the case if the view that the fibrous tissue is formed from the liver parenchyma were the correct one. Indeed, from these considerations, I feel considerable reserve in adopting that view.

Postscript.—Since the above was written two papers have reached me which require a brief mention. Nicati and Richaud (*Arch. de Phys.* 1880, p. 303) describe a biliary cirrhosis in rabbits, where the biliary ducts were the seat of parasites. They also trace the proliferation of the biliary canals from the liver-cells, which undergo active nutritive changes, and show fusion of protoplasm with proliferation of nuclei; small circular masses of embryonic cells are thus formed, which, by the disappearance of the centrally situated cell and the change of the peripheric cells to epithelial cells, form thus biliary canals.

Popoff (Virch. *Arch.* 1880, vol. lxxxi. p. 525), in studying the commencement of the biliary capillaries by ligaturing the bile duct in animals, found marked proliferation of biliary ducts, especially in rabbits, and adapts Charcot's rather than Litten's view as to their causation.

A CONTRIBUTION TO THE PATHOLOGICAL ANATOMY OF LEAD-PARALYSIS. By SIEGMUND MORITZ, M.D., L.R.C.P., *Assistant Medical Officer to the Manchester Royal Infirmary.* (PLATE IX.)

(From the Pathological Laboratory of the Owens College).

LEAD-PALSY is so common a disease, that its clinical phenomena can be frequently observed, and they have been recorded again and again with the minutest accuracy; but the morbid anatomy of the various organs affected by the poison has only been investigated in a very limited number of cases.

In almost all previous cases the pathological anatomy of which has been satisfactorily described (altogether only seventeen in number, so far as I can ascertain), the specific phenomena of lead-paralysis were far advanced; in some of them the muscles not only of the upper but also of the lower extremities had suffered extreme atrophy during life, added to which the supervention before death in most cases of eclampsia and other symptoms of severe implication of the central nervous organs, marked the majority as of established chronicity.

The case which offered itself for my observation, and which I am about to describe, differs from all those hitherto recorded, inasmuch as the patient died within six weeks subsequent to the supervention of one of the earliest symptoms of lead-palsy, namely, the dropped wrist, though he had been suffering for some time from the effects of lead. But as all the previous cases have been treated of in foreign literature, it may be desirable to give a short *résumé* of these.

Lanceraux (1) described three cases which he had occasion to examine after death. One was that of a woman, thirty-seven years old, who had suffered from arthralgia, epilepsy, and for ten years from paralysis of the extensor muscles of the forearm; she died of atrophy of the kidneys, and Lanceraux found the cord of diminished consistence in the region of the cervical intumescence, some ganglion cells atrophied and granular, some

nerve roots above the cervical swelling atrophied, the nerve fibres granular, the musculo-spiral nerve atrophied, and the medullary substance of its fibres degenerated.

In both the other cases of Lanceraux the spinal cord and nerve roots were unaffected, but the branches of the musculo-spiral nerve were atrophied, and their sheath showed a granulated degeneration.

Gombault (2) gives a full account of the pathological conditions found in a female, aged forty-eight years, who had shown about ten years before her death the first symptoms of lead palsy. The extensor muscles of both forearms were atrophied, and there was the well-known paralysis of these muscles; those of the lower extremities being also diseased, the standing position was extremely difficult, walking impossible. At the *post-mortem* examination the muscles presented three distinct changes. Some, though moderately atrophied, appeared normal to the naked eye; others were pale, and in colour similar to the "muscles of fishes," and these had undergone a considerable diminution in volume. Finally, the third sort looked like "smoked ham;" they were considerably enlarged in bulk, of red-brown colour, of wooden hardness, and so rigid that a long muscle detached from its insertion and supported by one end could be held horizontally extended, without any tendency to become bent. A combination of these three states could be met with in the same muscle. Neither the spinal cord nor the nerve roots presented any abnormalities. But the peripheral parts of these nerves showed considerable alteration. A large number of the nerve fibres were distinctly reduced in calibre, and contained only a small quantity of granular myeline, whilst some were completely atrophied, and included only a series of ovoid nuclei. Gombault ascertained that this alteration depended upon a development of the intra-fascicular connective tissue, and the proliferation of nuclei was particularly expressed in the neighbourhood of vessels. Those of the muscles which appeared least coloured to the naked eye showed all anatomical forms of chronic muscular atrophy when examined by the microscope. Simple diminution of volume, with conservation of the transverse striation, was the alteration most frequently met with, granular or fatty fibres being rarely found. Apart from this, a development of

interstitial connective tissue and nuclei could be easily distinguished.

I may be pardoned for giving this case so fully, inasmuch as the anatomical lesions presented by Gombault's case were very similiar to those of the case observed by myself.

The fifth case described is one by Westphal (3). The paralysis had lasted two years. No important alterations in brain or cord. The radial nerve showed a decrease of medullated fibres, which were surrounded by fibres, considered by Westphal to be regenerated nerve fibres.

The sixth case is one by Tiburtius (4). She could not find anything abnormal in brain or cord. The musculo-spiral nerve showed fibres similar to those described by Westphal, but surrounded by lamellar connective tissue. The more important changes were found in the intramuscular nerve fibres; these were highly atrophic.

Friedlaender (5) has recently described a case as follows. A painter, æt. fifty-nine, who had colic the first time four years ago, began to suffer two years later from paralysis of both arms, from which he recovered in seven weeks. His last illness began about six weeks before his death. There were no alterations of significance in brain or cord. The muscles were only imperfectly developed, a far-advanced atrophy was found in both pectorales majores muscles, as well as in the extensores of the forearm; the nerve fibres going to the latter appeared grey and atrophic. Microscopically examined, the muscles showed proliferation of nuclei, some of the nerve fibres appeared thinner, in extremely atrophied places abnormal development of connective tissue and proliferation of connective tissue corpuscles could be seen. The intramuscular nerve fibres appeared to be degenerated into "wave-formed tissue," with proliferation of corpuscles; also the extramuscular nerve fibres were highly degenerated; in some of the fibres the myeline was broken up, other fibres appeared very thin and wave-formed, with development of nuclei. There was a degeneration of motor nerve-root fibres.

Leyden adduces a case by Ollivier (6), who found an alteration in the paralysed muscles and also in the musculo-spiral nerve; most of the nerve fibres were healthy, but some were thinned, and showed fatty granulations.

Zunker (7) examined, under the superintendence of Leyden, a case of far-advanced generalised lead-paralysis. The brain and cord showed no important alterations, whilst the peripheral nerves presented an augmentation of nuclei, the myeline substance broken up, and formation of fat globules in the medullary sheath. On cross section of the radial nerve the distinct appearance of degenerative neuritis was obtained. This neuritis decreased towards the centre, and was not recognisable in the roots. The muscles showed a far advanced myositis, with fibrous degeneration, proliferation of the nuclei, thickening of sarcolemma, degeneration and atrophy of the contractile substance, development of adipose tissue, and formation of tendon-like tissue in place of the muscles..

Eisenlohr (8) is quoted by Zunker. He found no alterations in the cord or spinal nerve roots.

In opposition to the above-mentioned cases, the authors of which all advance it as a theory that the primitive lesions take place in the muscles or in the intramuscular nerve fibres, Vulpian (9) has already seen alterations in the spinal cord of a man who had, in consequence of lead-poisoning, paralysis of the extensor digitorum muscles. Some nerve cells contained vitreous colloid masses, whilst other cells were on the way to atrophy, with perhaps a tendency to the multiplication of nuclei. Sclerotic patches were found in the nerve roots of the cervical enlargement; the peripheric muscles and nerves were altered. Experimental investigation in a dog also showed a considerable alteration in the cord; in many places the nerve cells were on the way to destruction, the nerve fibres were altered, atrophied, a large number of granular bodies were present,—lesions which Vulpian identifies as those of subacute myelitis.

Déjérine (10) examined five cases of lead-paralysis, and always found alterations in the musculo-spiral nerve; in three of his cases alterations were likewise discovered in the anterior nerve roots; and in regard to the spinal cord, he follows the view which makes the paralysis dependent upon a lesion of the grey substance.

Monakow (11) described lately the case of a painter who had suffered for more than ten years from paralysis of the extensor muscles of the right hand, and in whom later on different symp-

toms of general paralysis and of a psychopathological nature supervened. He found after death myositis, the radial nerve only little altered, but considerable alterations in cord and brain.

In all these seventeen cases of lead-paralysis, which are the only ones respecting which reliable pathological data are available, the paralysis had existed for a long time (in Vulpian's case the time is not stated); in most of them symptoms similar to those of progressive muscular atrophy had developed themselves, and in some during life eclamptic and epileptic phenomena; in Monakow's case, cerebral symptoms had existed, which of course made it probable that lesions in the brain and cord would be found.

The following case, which came—as a home-patient of the Manchester Royal Infirmary—under my own treatment, had shown symptoms of unilateral peripheric paralysis for six weeks only before his death. The patient was a glass-founder, aged forty-five years, who had been in this occupation for about two years, during which period he had constantly been exposed to the influences of lead. He stated that during the last year he suffered repeatedly from colic, which had compelled him to discontinue his work at times, but he always resumed his occupation. Six weeks before I saw him, work had become impossible to him on account of paralysis of the extensor muscles of the right forearm, which had in the course of a few days made its appearance. When I saw him he looked extremely anæmic, complained of colicky pain in the abdomen, loss of power in the right forearm, and weakness in the left forearm. He felt very ill, and had severe headache.

The gums showed distinctly the characteristic blue lines. The right arm presented the well-known "dropped wrist," and extension of the hand was impossible, whilst the left arm was less affected. The muscles felt somewhat soft and flabby, but did not seem particularly wasted. The organs of respiration were normal. The heart sounds were loud, but the normal area of heart-dulness a little increased. The abdominal walls were retracted. The lower extremities were slightly œdematous, but their muscles still retained their power. The urine was pale, of low specific gravity, and contained a considerable quantity of albumen.

When I saw him on the next day he was in a comatose condition; he had had repeated convulsive fits, two of which occurred in my presence. He died the same day. The cause of his death was uræmia.

Only with the greatest difficulty was permission obtained to examine "the sinews of the arm and back," but nevertheless Drs Dreschfeld and Young succeeded with me in obtaining a piece of the musculo-spiral nerve, which showed on inspection no changes to the naked eye; a piece of the extensor digitorum communis muscle, which, compared with the supinator longus, presented a pale appearance; the spinal cord, which showed no abnormalities on inspection; and the left kidney, which had to be taken out by nephrectomy, the opening of the abdomen being strictly prohibited by the relatives. I have to thank Drs Dreschfeld and Young for the kindness with which they helped me in the performance of this necessarily incomplete autopsy, which was beset with many difficulties of a varied character. I have also to thank Dr Young, Pathological Registrar to the Manchester Infirmary, for the accompanying drawings, and Dr Dreschfeld for his kind assistance in the microsopical examination, the results of which were as follows:—

The left kidney, which weighed 6½ oz., and had a somewhat adherent capsule, was granular on its surface, showed a few small retention cysts, and the diameter of its cortex was distinctly diminished. On microscopical examination, the Malpighian bodies were seen to be considerably changed; some showed only a proliferation of nuclei and a thickening of their capsule, whilst others were completely degenerated, and welded into homogeneous lumps, presenting a hyaline appearance. The convoluted tubes were more or less atrophied; their epithelium presented a cloudy aspect, their laminæ were studded with tufts of needle-like crystals of uric acid. The epithelium of the straight tubes showed also a cloudy degeneration. The interstitial connective tissue was increased; the vessels were much thickened, and showed endoarteritic changes. In brief, the kidney showed a chronic interstitial nephritis, in which the large amount of uric acid crystals present in the tubes appeared remarkable.

The extensor digitorum muscle, which was taken from the right forearm, was first examined in its fresh state. Some of

the preparations were stained in logwood, and the following remarkable alterations were then seen (see fig. 1).

Most of the fibres present their normal striation, only a few show any cloudiness or intumescence. Many fibres tend to split up into longitudinal fibrillæ, or the sarcolemma appears to break up into spindle-formed fragments of various sizes. Most of these fibres still show their transverse striation, but some of them are converted into uniformly granulated cylinders. Some fibres show curvatures and swellings, and some a tendency to split transversely. But even those which are the least altered show proliferation of nuclei. In some places three or four large nuclei are found closely lying one on another; almost all the nuclei appear enlarged, and some show under an immersion power that they possess several granular bodies like nucleoli.

Nearly all these different stages of muscular atrophy can be observed together in one and the same preparation; side by side with the normally striated fibres there are some which appear to break up longitudinally, whilst others appear cloudy and granular. Some again are diminished in volume, with great proliferation of nuclei; others are swollen, with a tendency to break up transversely.

If we consider these alterations in the muscle as a whole, we must certainly acknowledge that they are extremely similar to those found by Friedreich (12) in progressive muscular atrophy.

A portion of the muscle was then hardened in bichromate of ammonia, and cross sections were made. The proliferation of nuclei in the muscular fibres, with in certain cases degeneration, became here again distinctly visible. But the most important alterations were seen in the intramuscular nerve fibres. The connective tissue of these appeared considerably thickened, and contained many nuclei. Every one of the primitive nerve fibres appeared to have a thickened sheath; in some the axis cylinder was still distinctly visible, whilst in others logwood and carmine staining only showed a homogeneous mass; nuclei were largely developed between the single nerve fibres (fig. 2).

Of the musculo-spiral nerve in its fresh state longitudinal sections were made and stained with osmic acid. The medullary substance was seen to be in a very varicose condition; in many places it appeared broken up into globular and irregular

masses. Comparing it with a healthy nerve treated in the same manner, this became distinctly visible. It appeared also as if Ranvier's nodes—étranglements annulaires des tubes nerveux (13)—were more than usually distinct in many places (fig. 3).

In longitudinal sections of the hardened nerve stained with logwood, one could distinctly see an enormous proliferation of ovoid nuclei, whilst in cross sections the medullary substance was seen to have disappeared in many places, the connective tissue to have increased, and its nuclei developed.

The spinal cord in its cervical region was carefully examined by Dr Dreschfeld, and in the remaining part by myself, but showed no abnormalities whatever.

If we now examine the various theories which have been advanced to account for the peculiar paralytic phenomena which are pathognomonic of lead-poisoning, we find that a great difference of opinion prevails. Remak (14) and Vulpian (9) think that a distinct group of cells situated in the cord a little above the cervical swelling is affected by lead, and that through this the paralysis is primarily caused. Friedlaender (5), Leyden, Zunker (7), and others, place the primary lesion either in the muscles or in the intramuscular nerve fibres; whilst some observers, on account of the peculiar galvanic and faradic reaction of the muscles, first described by Eulenburg (15) and Erb (16), place the primary lesion in the nerve itself.

Harnack (17) has, through experiments on animals, come to the conclusion that the symptoms of lead-paralysis are due to an action which lead exercises on the striated muscles. The circumstance that the muscle at first does not become unexcitable, but only very quickly tired, renders intelligible the fact that though muscles paralysed by lead do not react to faradic stimuli, and therefore cannot be thrown into tetanus, are still able to react on the application of galvanism.

Our case speaks much for the theory that the primary lesion takes place in the muscle, but it shows also that the intramuscular nerve fibres, and the musculo-spiral nerve itself, undergo degenerative changes, which, if not preceding, appear at least coincident with those of the muscular structures. Of the muscle only small tracts were affected, whilst others were perfectly healthy; the intramuscular nerve-fibres were more

uniformly and more extensively affected, and hence it is probable that the process commenced in them, and that the myotic changes were merely secondary.

I regret very much that the unfavourable circumstances under which the patient was observed prevented me from examining more carefully the clinical features of the nephritis, for there can be no doubt that the nephritis from lead-poisoning is likely to throw a good deal of light on the pathology of Bright's disease. From the examination of the kidney, it is quite evident that the patient suffered from interstitial nephritis. There was, however, also a distinct cloudy degeneration of the epithelial cells in the contorted tubules, and a similar change in the cells of the straight tubules; it was, however, seen that in many places the altered epithelium was found in the immediate neighbourhood of the impacted uric acid crystals, and it is therefore highly propable that the altered condition of the epithelium, especially as it was found also in the collecting tubes, where a number of these crystals were also found, was a secondary effect, and due to the irritation set by these crystals.

Lastly, it is to be remarked that during life distinct cardiac hypertrophy was observed and noted, but, unfortunately, the difficulties under which the *post-mortem* was performed prevented me from verifying this by an inspection after death.

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EXPLANATION OF PLATE IX.

Fig. 1. Muscle-fibres.—*a*, Showing tendency to split transversely; *b*, showing tendency to split longitudinally; *c*, narrowed fibre, showing disappearance of striation and great increase of nuclei; *d*, fibre, showing granular degeneration, with curvatures and swellings; *e*, granulated fibre, with proliferation of nuclei; *f*, very degenerated fibre, granular and swollen; *g*, fibre breaking up into spindle-formed fragments.

Fig. 2. Cross-section through muscle and intramuscular nerve.—*a*, Cut muscular bundle, showing proliferation of muscle nuclei and increase of connective tissue; *b*, thickened sheath of nerve with proliferation of nuclei; *c*, nerve fibres not degenerated; *d*, degenerated nerve fibres; *e*, small artery, with increase of connective tissue.

Fig. 3. Longitudinal section through musculo-spiral nerve (osmic acid preparation), showing broken up myeline and (*a*) Ranvier's nodes.

Fig. 4. Longitudinal section through nerve (logwood preparation), showing proliferation of nuclei and increase of connective tissue.

ON VASCULAR LESIONS IN HYDROPHOBIA AND IN OTHER DISEASES CHARACTERISED BY CEREBRAL EXCITEMENT.

By GEORGE S. MIDDLETON, M.A., M.B., *Assistant to the Professor of Practice of Medicine in the University of Glasgow.* (PLATE X.)

DURING the past few years considerable additions have been made to our knowledge of the pathological appearances found in hydrophobia. Congestion of various organs and of the mucous membranes have long been known to be present in such cases, and some of the older observers specially noted the congested appearance of the medulla oblongata and of the spinal cord; Mayo, indeed, recording not only the fact but the opinion that such vascularity was the effect and not the cause of the nervous symptoms. This was all that was known until the microscope was employed in these investigations, but since then various additions have been made to our knowledge of the histological changes, especially in the brain and cord.

At the Pathological Society of London, in 1872, Dr Clifford Allbutt exhibited a series of microscopic sections from the cerebro-spinal centres of two cases of hydrophobia, showing the following conditions:—

1. Evidences of vascular congestion, with transudations into the surrounding tissues. In all the grey centres the vessels were seen in various degrees of distension, with their walls often obviously thickened, and showing patches of nuclear proliferation.

2. Hæmorrhages of various sizes. In many places a refracting material was visible outside the vessels, due apparently to coagulated fibrinous exudation.

3. Little gaps, results of the granular disintegration of Clarke.

4. Affection of the parts in the following order: *a*, medulla; *b*, spinal cord; *c*, cerebral convolutions; *d*, central ganglia.

In 1877 Benedikt, in Virchow's *Archivs*, described the appearances in one case of hydrophobia and in several of rabies, specially insisting on the "miliary" character of the changes. He observed the nervous tissue infiltrated with nuclei, and hyaloid masses in the walls of the vessels, often constricting them, and due to the transformation of blood corpuscles. In

May of the same year, Dr Gowers exhibited before the Pathological Society of London a series of sections, illustrating the changes in the medulla and spinal cord in four cases of rabies. His paper was published in the *Transactions* of the Society for 1877, accompanied with numerous illustrations. He found the vessels of the grey matter greatly distended, and in three of the cases aggregations of small cells within the perivascular lymphatic sheaths, and infiltration of the tissues with the same, especially in the neighbourhood of the hypoglossal, glossopharyngeal, and pneumagastric nuclei. This latter point he considered of interest, as indicating a relation between the pathological lesion and the clinical phenomena of the respiratory system.

At the Royal Medical and Chirurgical Society of London, in December 1877, Dr Coats recorded the results of his examination of two cases of hydrophobia that had occurred in Glasgow. He described more definitely the perivascular exudation of leucocytes, and a similar aggregation of leucocytes around the ganglion cells and in the neighbourhood of the cicatrix. At the same time he had examined two cases of rabies in the dog, and he had found a general infiltration of the salivary glands with round cells, especially outside of the veins, a similar though less pronounced infiltration of the mucous glands of the mucous membrane of the larynx, and an excess of white corpuscles in the distended veins of the kidney. "The existence of signs of irritation in all these organs, and the direct connection of these signs with the blood-vessels," he considered "exceedingly suggestive of some irritant in the blood which had acted on the vessels primarily."

Since that time other observers have recorded cases, confirming generally previous observations, and dwelling mostly on the nervous lesions.

Two cases of hydrophobia have died in the Glasgow Royal Infirmary this year, the one in January and the other in April. Both were under the care of Dr Charteris, who will shortly publish their clinical history, so that it is only necessary to say that they were typical cases.[1] Dr Foulis, pathologist to the Infirmary, made the *post-mortem* examinations, and entered the following notes in the journal:—

[1] *Lancet*, Sept. 25, 1880.

First Case, 9th January 1880.—"On the back of the fore-finger there is a healed cicatrix, slightly thickened and reddish, and a smaller one over the base of the second metacarpal bone. The nerve centres are everywhere of normal appearance, with the exception of slight passive overfilling of the veins. Larynx, fauces, salivary glands, gullet and middle ears normal. There is a hard, nodular, calcareous mass, as large as a pigeon's egg, occupying the middle of the thyroid gland. Ecchymosis under the pericardium over the left ventricle. Heart almost empty, with the exception of the right auricle, which contains a couple of ounces of dark, thick semiclotted blood, and on removing the heart several ounces of similar blood are seen to regurgitate from the aorta and vena cava. The heart tissue and structure are normal. Lungs not adherent; both dark red, and emphysematous at the apices. Back part of right lung dark red, hardly crepitant, engorged with blood and serum. Trachea and bronchi do not call for remark. Bronchial glands not enlarged. Stomach contains a little greyish fluid; its lining is slightly discoloured but not ulcerated. Spleen dark, firm, but not enlarged; contains a large hæmorrhagic infarct. Liver dark and firm. Gall ducts patent. Bladder contains a little clear urine. Kidneys of normal size; capsule slightly adherent; cortical substance not thickened; colour pale purple. Bowels normal; here and there passively congested."

Second Case, 25th April 1880.—"Mark of a cicatrix through the right thumb nail. Careful examination of the head and its contents, including the eyes and ears, fails to show anything unusual, with the exception of a slight overfilling of the blood-vessels in the brain and a little serous effusion in the membranes over the back part of the hemispheres. The overfilling of the blood-vessels affects chiefly the smaller veins and capillaries, and it imparts a slightly reddish hue to the medulla, pons, and corpus striatum, while the cut vessels seen in the sections of the hemispheres are more numerous than usual. The serous membranes exhibit a slight passive overfilling of the smaller veins. Heart contains fluid, dark red blood in moderate quantity in all its cavities; valves and structure healthy. The lungs present old adhesions; they are of a pale rose colour mottled with grey; crepitant. Larynx, trachea, fauces, and gullet normal. Bowel

and stomach somewhat injected, about 4 inches of the lower part of the ileum being of a dark red colour, and dotted with numerous punctiform hæmorrhages. Kidneys, liver, spleen, pancreas, salivary glands, and suprarenal capsules exhibit slight passive hyperæmia. Microscopic examination for organisms in the blood and saliva negative."

Portions of the various organs were preserved for more minute examination, and these by the kindness of Dr Foulis were placed at my disposal. In this paper, then, I propose to give an account of the appearances observed, and a comparison of the nervous vascular lesions with those found in other cases marked by cerebral excitement.

At the outset it is necessary to state the methods of preservation and of examination, as there can be little doubt that the results obtained in the investigation of lesions, particularly of the brain and cord, vary with the modes of preservation and examination. In all the following cases the parts were preserved in spirit, some being rapidly hardened for convenience in absolute alcohol. Sections were cut with the razor in the usual way, and mounted either unstained in glycerine, or stained in dammar. Various aniline dyes were tried as staining agents, but the staining, though sometimes of service, was too uniform to give good results generally. The following descriptions are therefore based on sections stained with logwood or with carmine. The ordinary logwood solution was employed, but, though Beale's weak carmine solution was sometimes used, most of the carmine sections were stained in a solution suggested to, and prepared for me, by my friend Mr M'Kenzie of the Glasgow Royal Infirmary. The recipe is contained in Redwood's *Supplement to the British Pharmacopœia*, and is as follows :—

"℞ Cochineal,
Salt of tartar,
Cream of tartar,
Alum, . . āā ℥i.
Distilled water, . . ℥viii.

"Boil the cochineal and salt of tartar in the water, then add the cream of tartar and the alum, and filter."

Diluted with an equal bulk of water, this solution stains sections

of the brain in about five minutes.[1] It is specially useful for staining nuclei and leucocytes, but it does not colour the nervous ganglion cells and connective tissue so well as Beale's fluid. Numerous sections were examined of each of the cases investigated.

The examination of the two cases of hydrophobia gave the following results:—

Spinal cord.—In both cases the cord showed evidences of congestion, many vessels being found distended with blood. In the first only one punctiform hæmorrhage was seen, in the grey matter of the dorsal region, while in the second case these hæmorrhages were frequent. But the most striking lesion was that around the vessels. In both it was very pronounced, numerous vessels being seen clothed with round cells, a condition which, in the second case, became clearly less intense as the sections were made lower in the cord. The grey matter was chiefly affected, due, as has been pointed out by others, to the greater frequency of vessels there. In vessels in which blood corpuscles could be recognised, there was no aggregation of white corpuscles along their walls, but there was a distinct covering of leucocytes around them. In the second case there was also a well-marked infiltration of the tissues with round cells, which was not characteristic of the first. These round cells were found everywhere, especially in the grey matter, but at various points there were collections of them so pronounced as to render Benedikt's expression, "miliary abscesses," descriptive enough (Pl. X. fig. 1). Leucocytes in the spaces round the ganglion cells, as described by Kolesnikoff in dogs, in 1875, and by Coats in man, were not observed. There were no doubt leucocytes round many of them, but these seemed evidences rather of the general infiltration than of a special selection of site. It was noted, however, that many of the ganglion cells were only in part stained by logwood or carmine, a large part of their contents being of a deep brown colour and highly granular, possibly owing to degeneration. In a few instances there were seen in the perivascular spaces rounded, glistening, transparent bodies, stained by logwood but not by carmine, and not encroaching on the

[1] This solution does not keep well; a fresh supply must be made after about a month.

lumen of the tube (fig. 2). These, however, are of frequent occurrence in all sections of the brain or cord hardened in alcohol, and probably have no significance. They resemble the amyloid bodies, but have no striation, and they vary greatly in size and in regularity of outline.

Medulla oblongata.—This also was the seat of congestion, and, in the second case, of hæmorrhages. The perivascular lesion was also well marked, but in the first case it was less so than in the cord, while in the second it was not more pronounced. In neither was there any preference for the neighbourhood of the nuclei of the cranial nerves, as mentioned by Gowers, though more affected vessels were seen in the posterior half of the medulla than in the anterior, vessels being more frequent there. Infiltration of the nervous tissue with round cells was well marked in the second case.

Pons.—Congestion was present in both cases, this region in the second case containing numerous highly-distended vessels, and also showing numerous minute hæmorrhages, which were entirely absent in the first. The perivascular lesion was less frequently seen than in the lower tracts, though many highly-affected vessels were observed.

Thalamus opticus, Corpus striatum, and Motor convolutions.—These presented less evidence of congestion, and no hæmorrhages. In the second case many of the vessels were seen to have granules of blood pigment in their perivascular spaces. The exudative lesion, though quite distinct in all of those regions, affected fewer vessels, and generally those of smaller size than in the lower centres. It may here be stated that the lesion was nowhere confined to vessels of capillary size, attacking generally those of medium size, and that infiltration of the tissues was less characteristic of the higher centres than of the lower. The rounded bodies described above were found in all the regions of the brain, and did not show that localisation in the perivascular sheaths noted in the cord.

Retina.—The retina was examined in the second case, but there was nothing to be noted about it, save engorgement of the vessels.

Cicatrix.—This was examined only in the second case. The thumb was immersed in a solution of chromic acid to decalcify

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Retina.—The retina was examined in the second case, but there was nothing to be noted about it, save engorgement of the vessels.

Cicatrix.—This was examined only in the second case. The thumb was immersed in a solution of chromic acid to decalcify

the phalanx, and sections were then made through its whole thickness. A careful examination failed to detect the presence of any leucocytes in or near the cicatrix; and though many vessels were examined, comparatively few were found congested. There were minute hæmorrhages here and there into the fatty tissue, as in other organs.

Salivary Glands.—These in the first case showed a few congested vessels, in the second many, as also punctiform hæmorrhages. Many of the distended vessels contained an excess of white corpuscles, seen both in their lumen and along their walls. There were also collections of round cells in and around the walls of several of the vessels, as well as in the connective tissue of the glands. In the drawing (fig. 3) a vessel is seen thus affected. The leucocytes are seen grouped on both sides of it, and on changing the focus they were seen above it. They are also apparent in the tissue separating the glandular elements. It appears, however, that much importance cannot be attached to this condition. Klein and Noble Smith point out[1] that "there are found in all parts of the connective tissue (of the salivary gland), both inter- and intra-lobular, isolated or small groups of migratory cells (Boll, Lavdowsky)." And my examination of the salivary glands, taken from cases in which they might be supposed to be healthy, showed that there is often an abundance of leucocytes, many large groups being seen in the connective tissue, in which both vessels and ducts lie embedded. Probably we have here a condition which always accompanies salivation; and in this connection it may be noted that the round cells were most abundant in the second case, in which the clinical record tells us that salivation (in both cases aided by the injection of pilocarpine) was a more marked feature than in the first.

Tongue.—The tongue was examined in the first case, and presented no striking lesion. There were no congested vessels seen, and no hæmorrhages; and it was not made out that there was any excess in the number of round cells.

Trachea and Pharynx.—In the first case there was little to be noted with regard to these, but in the second their mucous membranes were highly congested, and numerous minute hæmorrhages were discovered. These tissues contain abundant nuclei and

[1] *Atlas of Histology*, part ix. p. 188.

round cells, so that it is somewhat difficult to make out any exudation of leucocytes, unless very extensive. A careful examination, however, seemed to show that there was some slight infiltration.

Heart.—In both cases this organ was congested, and punctiform hæmorrhages were seen—conditions which were much more pronounced in the second than in the first case. In the latter there were also seen some granular masses, presenting the appearances of altered blood-clot. Some of the congested vessels (both arteries and veins) exhibited an excess of white corpuscles, and had small collections of round cells in their sheaths. The connective tissue separating the muscular fibres of the heart contains nuclei; but there was an apparent increase of these, there being here and there visible small collections of round cells. In the drawing (fig. 4) there is seen such a collection of round cells in the connective tissue around some fat cells. On comparison with sections of the heart from other cases, however, the significance of these round cells is somewhat doubtful.

Lungs.—Here also were found highly-congested vessels and abundant hæmorrhages, the pulmonary vessels being over considerable areas engorged with blood. A careful examination of these, along with other lungs, seemed to show that there was a slight infiltration with leucocytes, chiefly in the neighbourhood of veins. But there was no marked aggregation of leucocytes about the vessels.

Liver.—In both cases the portal and hepatic veins were found to be greatly distended. In cross section these vessels were often seen of very large size, the blood corpuscles looking as if they had run together in groups, and thereafter been changed into a granular or hyaline substance (fig. 5). There were but few traces of hæmorrhage. There was no marked infiltration of the tissue with round cells, but they were seen in considerable numbers, especially in the neighbourhood of the portal circulation. In the normal liver there were observed somewhat similar, though less marked, collections of round cells; while in the liver, from a case of purpura hæmorrhagica, there was a most pronounced infiltration.

Kidneys.—These shared in the general congestion, and showed

minute hæmorrhages, especially in the cortical portion. The congestion chiefly affected the veins, the sections of some of which were filled with an altered, granular material. In no case was there seen to be any aggregation of the white blood corpuscles along the walls of the vessels. There was no infiltration with leucocytes.

Spleen.—The spleen was congested in both cases, and presented a large hæmorrhagic infarct in the first, and minute hæmorrhages in the second. As stained in logwood or in Redwood's carmine, the normal spleen exhibits an enormous number of nuclei and round cells, and the latter are distinctly most abundant in the neighbourhood of the vessels. In the cases of hydrophobia these appearances were intensified, partly owing to the fact that in the one case the sections were made through the infarct, in which little or no splenic tissue was visible. In the drawing (fig. 6) such a section is represented, and it will be seen that the round cells (the darker ones) are very abundant, the vessel which they surround being all but collapsed.

Pancreas.—The pancreas was congested, but no hæmorrhages were seen. Round cells were found in the tissues separating the glandular elements, but they showed no tendency to aggregation round the vessels, and they were not abundant.

Suprarenal Capsules.—These were examined in the first case, and contained numerous distended vessels, with a few minute hæmorrhages. In some of the vessels there was evidently an excess of white corpuscles, but there was no clothing of the vascular sheaths with leucocytes. The glandular elements were separated by a tissue containing round cells, groups of which were also found scattered about, especially in the neighbourhood of the vessels. They were not, however, compared with the same structures from other cases.

Intestines.—These were congested in various places, and presented occasional minute hæmorrhages. The appearances were similar to those of other tissues containing mucous glands.

As compared with each other, the second of these cases exhibited the most marked lesions. Not only was congestion deeper, and hæmorrhage much more frequent than in the first case, but the vascular lesion and the infiltration of the tissues in the brain and cord were much more pronounced. There is

nothing in the clinical record to account for that. The symptoms in both were very acute, and the disease terminated fatally, after about the same duration. The only difference in the treatment was that in the second case pilocarpine was pushed much more assiduously than in the first, and perhaps that had something to do with the appearances presented after death.

With the view of determining the importance to be attached to the perivascular lesion in the nervous system, portions of the brain or cord were preserved in twenty-four other cases, not taken consecutively from the *post-mortem* room, but selected as more or less likely to have been attended with nervous symptoms. These were examined microscopically, and thereafter the clinical records were consulted to see if any relation such as was suspected could be shown to exist. The results obtained are given below.

Purpura Hæmorrhagica.—The clinical history of this case appeared in the *Glasgow Medical Journal* for June. No cerebral symptoms were noted. At the *post-mortem* examination there were found numerous punctiform hæmorrhages in the white matter of the cerebrum, and in the corpora striata and optic thalami. The microscope revealed an exceedingly well-marked lesion of the vessels, quite similar to that seen in hydrophobia. In the motor convolutions numerous affected vessels were observed, mostly of considerable size. There was also a general infiltration of the tissues with round cells, in many places presenting the appearance of "miliary abscesses." Exudation of hæmatin was also very general. The corpus striatum, island of Reil, pons, medulla, and cerebellum were also examined and found to present the same lesions. It was noted, however, that there was a marked tendency to diminution of its intensity as the sections receded from the convolutions. The heart, lungs, liver, and kidneys presented much the same appearance as in hydrophobia; but in the liver and kidneys, especially in the former, there was a striking infiltration with round cells. In the liver this was chiefly round the hepatic veins.

Diabetes.—Three cases examined.

First Case.—No cerebral symptoms noted until the day before death, when persistent vomiting, great prostration, restlessness, and inability to speak were recorded. At the *post-mortem* the

brain was found to be healthy and free from injection. The convolutions and the optic thalamus alone were examined, and in neither was there found any exudation of leucocytes.

Second Case.—No cerebral symptoms, unless persistent vomiting, commencing about ten hours prior to death. Brain set down as normal at the *post-mortem* examination. The medulla, pons, floor of fourth ventricle, and corpus striatum were examined. Congested vessels were seen in all these situations, though not many, and in the corpus striatum one minute hæmorrhage was found. Leucocytes outside of the vessels were not seen, but here and there, especially in the floor of the fourth ventricle, a vessel was found in section with an aggregation of white corpuscles along its walls, and at other times a vessel with slight collections of round cells in its walls.

Third Case.—This patient was long under observation, and was considered to have a decided mental want, which occasionally led to slight excitement. The *post-mortem* examination showed the brain to be firm and congested. The medulla, pons, motor convolutions, and cerebellum were examined. In the latter one or two vessels displayed an aggregation of round cells in patches along their walls; while the other parts were congested (especially the pons), and exhibited numerous vessels with collections of white corpuscles within them, round cells aggregated along their sheath, and slight infiltration of the tissues with leucocytes, tending occasionally to the formation of miliary abscesses. These lesions were not so pronounced as in hydrophobia.

The lesions described by Dickinson were not seen in any of the cases of diabetes.

Head Injury.—Four cases examined.

First Case.—The patient was admitted into the hospital with fracture of the skull, and was never conscious, dying three days after admission. There was fracture of the skull from the coronal suture down through the petrous bone on the right side, and across the basilar portion of the occipital. Great effusion of blood at the base on both sides. Brain much lacerated, and of a dark brown colour at the seat of laceration. The three regions examined—medulla, pons, and corpus striatum—all showed well-marked vascular lesions similar to those described in hydro-

phobia, and in some parts quite as pronounced. This condition was most intense in the medulla (fig. 7), especially in the neighbourhood of the nuclei of the cranial nerves. Only an occasional vessel was observed full of blood, and then there was an aggregation of white corpuscles within it.

Second Case.—Scalp wound without fracture; erysipelas of head; great delirium, and death after fourteen days. The *post-mortem* inspection revealed slight passive congestion of the brain. The sections contained no congested vessels, but many showed a slight exudative lesion. These were principally in the pons and in the medulla, without any special relation to the nuclear region. Exudation of blood pigment had also taken place.

Third Case.—Head injury complicated by hæmatoma. Patient lived for six weeks, and showed considerable mental aberration and excitement. The medulla, pons, and corpus striatum showed evidences of slight congestion, and one punctiform hæmorrhage was seen. The exudative perivascular lesion was quite as well marked as in hydrophobia, especially in the medulla, where vessels both large and small were seen embedded in leucocytes.

Fourth Case.—This patient was admitted with symptoms of severe concussion, was very delirious, and died in about twenty-four hours after receipt of his injuries. The *post-mortem* examination revealed a little effused blood in the scalp and between the dura mater and the arachnoid over the posterior surface of the left occipito-parietal lobe. The brain was otherwise normal. There was fracture of the dorsal spine, one of the fragments slightly compressing the cord. The medulla, pons, corpus striatum, and motor convolutions were examined. There was no congestion anywhere, and no strongly marked perivascular lesion; but in each of these regions a few vessels were observed with collections of round cells in their walls.

These four cases of head injury all showed a lesion similar to that found in hydrophobia, but in two of them it was very slight. In all there was great cerebral excitement, and the case in which this lasted for the shortest time showed least evidence of the perivascular lesion.

Delirium Tremens.—Two cases were examined.

First Case.—This was one of delirium secondary to a slight scalp wound followed by erysipelas. The patient was delirious

for a week or more, and at times much excited. The vessels of the brain and of its membranes were found to be slightly overfilled, but there was no inflammation. There was no fracture of the skull, and no injury to the brain could be detected. Hæmorrhage into the right eyeball had taken place. The medulla was but slightly congested, the pons more so, and the motor convolutions were deeply congested and presented a number of minute hæmorrhages. In the medulla and convolutions a few vessels, and in the pons many, were found with a marked collection of round cells in and around their walls.

Second Case.—This was a case of delirium tremens pure and simple. The convolutions alone were examined, and were found deeply congested. Along a few of the vessels of almost capillary size there was seen a slight collection of round cells, scarcely amounting to a lesion.

Opium Poisoning.—This patient presented the usual symptoms of an overdose of opium, and died about twenty-four hours after the poison was taken. The *post-mortem* examination detected no lesion of the brain or cord. The cord, medulla, pons, central ganglia, and convolutions were examined, and found to display no trace of congestion. The central canal of the cord was much distended, containing a granular material and many nuclei or round cells. There was no decided perivascular lesion visible anywhere in any of the above regions.

Diphtheria.—This was a case of a child, who also suffered from caries of the spine. There were no cerebral symptoms. The *post-mortem* examination discovered no lesion of the brain, nor did the microscope.

Peritonitis, Cirrhosis of Liver, &c.—This case had no cerebral symptoms, and the brain and cord were found to be normal in appearance. The medulla, pons, corpus striatum, and convolutions were examined, and presented evidences of slight congestion, especially the medulla and the pons. In these latter regions there were also found vessels in and around the walls of which there were small collections of round cells; but such affected vessels were few in number and mostly in the medulla. Many of the ganglion cells in the medulla were obviously enlarged, and some were of a deep brown colour and highly granular, showing no trace of nucleus.

Chronic Hydrocephalus.—In this instance there were distinct evidences of cerebral excitement over a long period. The *post-mortem* inspection showed the dura mater deeply congested, the brain tissue of normal consistence, and the ventricles of the brain enormously distended. The spinal cord appeared healthy. The cord only was examined, and it was found to be normal.

Phthisis.—The clinical record contained no note of cerebral excitement in this case, and the *post-mortem* showed the brain to be normal. The medulla, pons, and corpus striatum were examined without finding any lesion.

Tubercular Meningitis.—Two cases examined.

First Case.—Decided cerebral symptoms for a considerable time. The inspection revealed thickening and matting together of the membranes in the Sylvian fissure, and a finely granular appearance resembling miliary tubercles in the matted membranes. The lateral ventricles were dilated with serum, but there was no thickening of their lining. No other disease of the brain was observed. The medulla and parts from the fissure of Sylvius were examined and showed no traces of congestion; but a few of the vessels displayed the perivascular lesion with considerable intensity. The walls of the capillaries were much thickened.

Second Case.—This was a case similar to the preceding. The lateral ventricles contained a considerable amount of fluid, and there was considerable thickening of the ependyma ventriculorum and congestion of the blood-vessels. Throughout the brain substance there were tubercular deposits. The vessels in the pia mater on the anterior part of the medulla were distended with blood and embedded in enormous collections of round cells, which showed no tendency to grouping suggestive of tubercles. The vessels dipping into the nerve tissue from the membranes had also collections of round cells in their sheaths, but to a much less extent, and near the affected portions of the pia mater there was a great infiltration of the nerve tissue with round cells. The walls of the vessels were often much thickened. Many of the ganglion cells were of a deep brown colour and granular, showing no trace of nucleus. In the pons and basal ganglia the perivascular lesion was scarcely visible.

Mental deficiency and excitement in an obscure case, possibly enteric fever. Head symptoms for a week or more. Brain alone

examined at the *post-mortem* inspection. The convolutions only were examined microscopically. Many vessels were found distended, and a few with the perivascular lesion (fig. 8).

Hæmatoma.—This patient suffered from symptoms referred to compression of the brain, such as nervous twitchings of the hands and arms, pain in the back of the head, &c. At the *post-mortem* there was found to be effusion of blood below the dura mater. The convolutions were compressed, but the brain and cord appeared to be healthy. The cord, medulla, pons, and corpus striatum were examined, and presented very little abnormality. The corpus striatum displayed a few distended vessels, and a number with small collections of round cells in and along their walls in patches. A few such vessels were also seen in the medulla, but the lesion was nowhere intense.

Peritonitis, Pericarditis, and Pleurisy.—This case had no cerebral symptoms, and the brain and cord were found to be healthy. Parts of the motor convolutions were preserved according to Hamilton's method, and sections were then cut with the freezing microtome. There was slight congestion, but no other lesion observed.

Spinal Abscess.—There were no symptoms of cerebral excitement. An abscess was found at the sixth dorsal vertebra compressing the cord, which alone was examined. There was no sclerosis apparent, but in the walls of a few of the vessels there were seen small groups of round cells, scarcely to be reckoned as a lesion.

Tetanus.—A typical case of tetanus, death taking place about five days after the onset of the symptoms. The inspection showed the scalp, skull, and dura mater congested, while the brain tissue was firm and healthy in appearance. The pons, corpus striatum, and convolutions were examined, and all presented slight traces of congestion, with one or two minute hæmorrhages. There was no marked vascular lesion, but many of the vessels had small collections of round cells in their walls. The nerve tissue, especially in the pons, presented numerous rounded gaps with regular outlines.

Uræmia.—Two cases were examined.

First Case.—Bright's disease of long standing, in the course of which there were frequent attacks of uræmic vomiting, twitch-

ings, and drowsiness. There was found to be considerable serous effusion into the ventricles and subarachnoid space. The ventricles were dilated, and the brain tissue pale and anæmic as well as moist. There were little hæmorrhagic points in the retinæ. The medulla, pons, thalamus opticus, and corpus striatum were examined, and each presented the same lesion round the vessels as had been seen in hydrophobia. The part most intensely affected was the medulla, where, besides numerous vessels clothed with leucocytes, there was great infiltration of the tissues, with here and th ~e "miliary abscesses." There was no congestion visible anyw here.

Second Case.—Also a case of Bright's disease, but with uræmic symptoms of only twenty-four hours' duration. There was found to be slight subarachnoid œdema, and the frontal lobes were pale, but there was nothing else to note about the brain. The medulla, pons, optic thalamus, corpus striatum, and motor convolutions were examined, and presented appearances similar to those found in the preceding case, though less intense and less general. In the convolutions it was noted that many of the smaller vessels could be traced by an exudation of the blood pigment.

To show more clearly the conclusions to be drawn from these cases, the annexed table has been constructed. It will be seen that of the twenty-four cases examined, fifteen showed the same perivascular lesion as hydrophobia, nine of them presenting it in a very marked form. Thirteen cases had had marked symptoms of cerebral excitement, and three had shown less intense symptoms; and of these sixteen only four presented no vascular lesion, two of which are noted as not having undergone a complete microscopic examination. Eight were not characterised by cerebral symptoms, and five of them presented no lesion. The conclusions may therefore be drawn, that the perivascular lesion is by no means characteristic of hydrophobia; that it is commonly found in cases characterised by cerebral excitement; and that the intensity of the lesion varies directly with the intensity and duration of the cerebral symptoms.[1]

As regards the pathology of hydrophobia, it still remains true

[1] In the *British Medical Journal* for June 26, 1880, similar appearances are described as having been found in a case of athetosis, by Dr Beach of the Darenth Asylum.

that nothing characteristic has been observed. The general vascularity, the frequent hæmorrhages, and the perivascular lesion with its accompanying infiltration of the nervous tissues, may all be indicative of the presence of an irritant in the system. But if so, they must be regarded as common results of irritation from various causes, and not as pathognomonic of any one poison or irritant, for they occur in widely differing diseases.

Tabular Statement of the Twenty-four Cases examined.

No. of Case.	Disease.	Cerebral Symptoms.			Perivascular Lesion.		
		Marked.	Slight.	None.	Marked.	Slight.	None.
1	Purpura	.	.	×	×	.	.
2	Diabetes	.	×[1]	.	.	.	×
3	Do.	.	.	×	.	×	.
4	Do.	.	×	.	×	.	.
5	Head Injury	×	.	.	×	.	.
6	Do.	×	.	.	.	×	.
7	Do.	×	.	.	×	.	.
8	Do.	×[1]	.	.	.	×	.
9	Del. Tremens	×	.	.	×	.	.
10	Do.	×	.	.	.	.	?[2]
11	Opium Poisoning	.	.	×	.	.	×
12	Diphtheria	.	.	×	.	.	×
13	Peritonitis	.	.	×	.	×	.
14	Hydrocephalus	×	.	.	.	.	×[1]
15	Phthisis	.	.	×	.	.	×
16	Tub. Meningitis	×	.	.	×	.	.
17	Do.	×	.	.	×	.	.
18	Indefinite	×	.	.	×	.	.
19	Hæmatoma	.	×	.	.	×	.
20	Peritonitis	.	.	×	.	.	×
21	Spinal Abscess	.	.	×	.	.	×[2]
22	Tetanus	×	.	.	.	.	?
23	Uræmia	×	.	.	×	.	.
24	Do.	×[1]	.	.	.	×	.
		13	3	8	9	6	9

[1] Symptoms lasted for only twenty-four hours or less.
[2] Microscopic examination incomplete.

AN ETHER PERCOLATOR, FOR USE IN PHYSIOLOGICAL OR PATHOLOGICAL LABORATORIES. By DONALD MACPHAIL, M.B. *From Path. Chem. Laboratory, Western Infirmary, Glasgow.* (PLATE XI.)

To thoroughly extract fatty or other matters soluble in ether from organic substances has always been a tedious and unsatisfactory proceeding, as a great many successive washings are required to make the process complete, the waste of ether is inevitably great, and if ordinary heat of a flame is used, the risk of a conflagration is considerable. The ordinary methods were found so troublesome and expensive during recent chemical investigations in the pathological laboratory of the Western Infirmary, that we found it necessary to devise some apparatus to economise both material and time. Such an apparatus was made, and, after many experiments and much modification and reconstruction, has assumed the form represented in the accompanying plate. It has been found very useful; it works safely and easily; and once set going will work for hours without further attention, keeping a continual stream of pure ether passing through the substance under treatment, and that with almost no loss of ether from evaporation. In the machine that has been used at the Western Infirmary, the chamber (E in fig. 1 of the plate) in which the substance under treatment is contained fills with ether and empties itself about ten times in quarter of an hour. As the chamber receives about 8 cc. of ether each time, it follows that the ether passes through at the rate of 320 cc. per hour, or 7 litres 680 cc. (about 1½ gallons) in twenty-four hours; and this it does with a loss of only about 40 cc. out of the 60 put in when the machine is set going. If the joints and couplings had been made absolutely tight, the loss would, of course, be much less. As it is, however, the loss is really inconsiderable, considering the amount of work the small quantity of ether is made to do. If necessary, the substance can be repeatedly boiled in ether without loss or risk, as the heat is got by the use of hot water from the taps with which laboratories are usually fitted up, so that should an escape

of ether vapour occur from any defects in the couplings or other joints, there is no risk of conflagration or explosion from contact with a flame. The apparatus is made of ordinary glass tubing, with india-rubber corks and grey tubing for couplings, and can be constructed by any one in a very short time, and at the expense of a few shillings.

First, to explain the construction of the apparatus, and then the manner in which it works.[1]

A long piece of glass tubing (A), about $\frac{1}{4}$ inch in diameter, is bent into a U shape, so as to have one limb 30 inches long, the other 24 inches, and the cross piece $3\frac{1}{2}$ inches. Upon each limb there is fitted a jacket (B^1, B^2) made of $\frac{3}{4}$ inch glass tubing, closed at both ends by india-rubber corks, through the centre of which the U tube passes, each jacket allowing the tube to project about 2 inches from its lower end. Each of the cylindrical jackets has an inlet pipe (x^1, x^2) blown on about half an inch from the bottom, and an overflow one (y^1, y^2) the same distance from the top. Each inlet pipe has a glass T-tube coupled on to it with india-rubber tubing, and the two overflow pipes are coupled to the ends of a T-tube, of which the stem (C) is turned up, and then bent over and carried to the sink. The end of the long limb of the U-tube, which projects through the cork closing the jacket, is bent, and passes through the india-rubber cork of the flask (D), and the end of the short limb passes through the cork (also india-rubber) of the test-tube (E). This test-tube has a hole (z), $\frac{1}{8}$ inch in size, made in it half an inch from the top, and there is blown on to the bottom of it a syphon (F) of fine glass tubing ($\frac{1}{8}$ inch), the upper bend of which reaches a little below the level of the hole in the test-tube, the end passing through the cork of the flask, and reaching almost to the bottom of that vessel. The flask is set in a tin canister (G), which has an inlet pipe, a T-tube of metal soldered in near the bottom, and an overflow pipe, also of metal, near the top. The T-tubes attached to the various inlet pipes (x^1, x^2), and that on the canister have each coupled on to the

[1] An apparatus, similar in principle to this, by Drechsel, is figured in Gamgee's *Physiological Chemistry*, vol. i. p. 265. The first description appeared in *Journ. of Prakt. Chemie*, vol. xv. (1877), p. 350.

free limb a short piece of india-rubber tubing, which can be closed by a clip when the apparatus is working; the stems of the T-tube (x^1) and that on the canister are connected by india-rubber tubing with the hot water tap, and that at x^2 with the cold water tap. The whole apparatus is fastened by hooks to an upright piece of board, with a movable shelf, on which the canister rests. The overflow pipe from the canister, like that from the upright cylinders (C), empties itself into the sink. The apparatus thus constructed is ready for use.

The ether is put into the flask, between two and three ounces being generally enough to keep the apparatus working for eighteen or twenty-four hours. The substance to be washed is put into the test-tube, a small pellet of purified cotton wool wrapped in muslin being first put in the bottom to act as a filter. The test-tube, syphon, and flask are then adjusted to the rest of the apparatus, the canister slipped over the flask from beneath, and the shelf put in below the canister. The hot water, which requires to have a temperature between 65° and 70° C., is turned on, and the clips put on the inlet tubes (x^1) and that on the canister, but kept off the one at x^2; the hole (z) in the test-tube is also left open. The hot water at once fills the canister, and flows up the long cylinder (B), down the short cylinder (B^2), and out by the open end of the T-tube at x^2. The ether soon boils, and the ether vapour in the heated tube drives out the air. As soon as the air has been expelled, which is seen by ether vapour escaping from the hole in the test-tube, close the hole with a small cork of india-rubber, put the clip on the T-tube at x^2, and turn on the cold water into the cylinder B^2, which drives the hot water out of that cylinder, bringing the long overflow pipe (C) into operation, and the apparatus is now ready to work for hours without further attention.

The ether, vaporized in the flask, is carried up the heated tube within the long cylinder, and is condensed in the tube within the short or cold cylinder. It flows down and collects in the test-tube till it reaches the level of the upper bend of the syphon, when it at once runs over into the flask again, carrying with it the dissolved matter, this process being repeated without intermission as long as the machine is kept working, or

sufficient ether remains to fill the test-tube up to the required level.

In this way, all the substances that are soluble in ether are thoroughly dissolved and washed out by being continually acted on by fresh quantities of pure ether, and as the process goes on they gradually accumulate in the flask.

To stop the machine, turn off the hot water, and open the clips at x^1 and that on the canister, so as to let the hot water run out of the apparatus, and at the same time open the hole at z, so as to allow air to enter as the ether condenses. As the hot water in the long cylinder runs out at x^1, the cold water from the other cylinder follows it across the T-tube at the top, and rapidly cools the whole apparatus, and the ether vapour is condensed, and flows back into the flask.

When it is wished to boil the substance to be analysed in the ether, the jacketed test-tube shown in fig. 2 is substituted for the simple test-tube and syphon. Here the test-tube is surrounded by a jacket of wide tubing, which has an inlet and an overflow pipe, corresponding with those on the cylinders, and the syphon is furnished with a stop-cock, which, when closed, prevents the ether from running over into the flask. When this has been fitted on to the apparatus, the ether is allowed to distil over into the test-tube, the stop-cock being closed. When as much ether has collected in the test-tube as is thought necessary for boiling, the hot water is turned off, and cold water is allowed to circulate through the two cylinders as described above, hot water being at the same time allowed to flow into the jacket of the test-tube till the ether in the test-tube boils. In this way the vapour of the boiling ether is condensed in the U-tube, and flows back, partly into the flask and partly into the test-tube; and when more ether is required in the test-tube all that has to be done is to turn off the hot water from the jacket of the test-tube, and set the apparatus going again till the ether re-accumulates. Of course, when the stop-cock on the syphon is open, the jacketed test-tube does perfectly well for the ordinary percolation as described above, so that an apparatus fitted up with it serves equally well for either boiling, percolation, or both combined. The only drawback to it is that if the stop-cock on the syphon is not carefully kept tight, leakage of ether

and the extract in solution is apt to take place through the joints.

This apparatus will doubtless ensure more accurate results in analyses of organic tissues than can be obtained by the methods hitherto in use in physiological or pathological laboratories. By increasing its size it would be available for much larger quantities, and should be found useful for making etherial extracts in pharmaceutical operations.

ON THE ... LUE OF CHLOROFORM AND ...)RIDE AS ANÆSTHETIC AGENTS. By DAVID NEWMAN, M.B. *Reported on behalf of the Committee on Anæsthetics of the British Medical Association.*[1]

In the last number of the Journal[2] we called attention to a series of experiments, performed with the object of studying the influence of anæsthetics upon the heart and pulmonary circulation, and from the facts obtained we considered ourselves justified in drawing the following conclusions:—

1. As in the experiments on the effects of the anæsthetics upon the blood-pressure, it may be stated that chloroform produces the most immediate effect, ether the least, whilst ethidene occupies an intermediate position.

2. The quantity of air, and the length of time required to restore the circulation in the lung, is in an inverse ratio to the amount of anæsthetic-vapour, and time necessary to stop it.

3. The changes produced in the lung are the same in all, the only difference being in the rapidity of their occurrence.

4. The anæsthetics produce the following changes in the lungs —(1) Slowing and ultimate stoppage of the circulation in the lung, first in the capillaries, then in the arterioles, and subsequently in the larger vessels; (2) the epithelium cells of the meshes and their nuclei are no longer apparent; (3) the capillaries contract slightly, and their walls become less distinct or even disappear from view, and the enclosed corpuscles may become more or less disintegrated.

5. The effect of ether and ethidene upon the heart, after artificial respiration for seven and five minutes respectively, is simply to produce a slowing of the impulses, ethidene having the more marked effect. Chloroform not only produces a slowing of the pulse, but the ventricular contractions are delayed and slightly

[1] The committee consists of John G. M'Kendrick, M.D., Professor of Physiology, University of Glasgow; Joseph Coats, M.D., Pathologist, and Lecturer on Pathology, Western Infirmary, Glasgow; and David Newman, M.B., Pathological Chemist, Western Infirmary, Glasgow.

[2] *Journal of Anatomy and Physiology*, vol. xiv. p. 495.

separated from the auricular, and an auricular contraction may immediately follow the ventricular. The auricular contractions frequently occur without any corresponding ventricular movements.[1]

In a report published in the *British Medical Journal*,[2] we related six cases in which ethidene dichloride had been used as an anæsthetic, and expressed our satisfaction with the results. Since then we have instituted a series of observations with the object of contrasting the effects of ethidene and chloroform. Subsequent to our directing attention to ethidene in January 1879, it has been used extensively throughout the country, and not long ago J. T. Clover, Esq., F.R.C.S., published in the *British Medical Journal* an account of *one thousand eight hundred and seventy-seven* cases.[3] In this paper he gives particulars relating to a case of death from cardiac syncope, *after* the administration of ethidene and nitrous oxide gas, the nitrous oxide having been stopped before the ethidene was given. At the *post-mortem* inspection the heart was found to be enlarged, and its fibres were shown to have undergone fatty degeneration. In some of his observations in connection with the cases in which ethidene was employed, Mr Clover calls attention to its depressing action upon the heart; to this point we shall refer. The committee believe that ethidene has been frequently used on the Continent, but they have found no published records except the above.

With the kind permission of the surgeons of the Western Infirmary, Glasgow, Professors Macleod and Buchanan, and Dr Patterson, we made the following arrangements. In Dr Buchanan's cases ethidene was administered, in Dr Macleod's chloroform, and in Dr Patterson's ethidene and chloroform month about. The observations, with a few exceptions, were conducted in the operating theatre, the temperature of which was on no occasion below 59° F. or above 64° F. The cases were not selected, except two cases of ovariotomy of Dr Macleod's, in which ethidene was given; the others were taken as they presented

[1] In connection with this point, Dr Coats is at present engaged with an investigation into the effect of anæsthetics upon the cardiac ganglia.

[2] 25th January 1879.

[3] *British Medical Journal*, 29th May 1880.

themselves. The anæsthetics were given invariably on a towel, the usual way of administering chloroform in Scotland, and in all the cases the patients were lying on their back. In order to facilitate the record of the cases, we prepared schedules in which all the particulars of each case were stated. We intend publishing the results in detail in an early number of the *British Medical Journal;* in the meantime, we will content ourselves with making more general observations, having regard only to points which can be brought out without referring to elaborate tables which we have not space to produce here. It may be here stated, that before making up these tables our general impressions as to the comparative results were somewhat different from what is shown in the figures before us. From fifty cases in which ethidene was given, the average dose may be stated as 40·3 cc., or in other words, 1·8 cc. for each minute during which the patient was under the anæsthetic; whereas, in the case of chloroform, the average dose is 31·8 cc., or 1·7 cc. for each minute. The method we adopted of administering the anæsthetic (on a towel) prevents us from arriving at a conclusion as to the amount of anæsthetic vapour which entered the patient's lungs; the results in respect to the doses are therefore only comparative. The time required to put the patient under chloroform is greater by 1·1 minute (5·4—4·3) than what is necessary to anæsthetise with ethidene. In connection with these observations, there are several points which must be taken into consideration;—first, owing to the average time during which the chloroform patients were under the anæsthetic being less (18 minutes), as compared with those who had ethidene (22·3 minutes), the dose per minute (1·7 cc.) is proportionately increased in the case of chloroform, for it is during the first few minutes that the greater quantity of the entire dose is administered. When the patient is once under the anæsthetic, a comparatively small quantity is required to keep him so. The same cause may also account for the difference in time necessary to recover from the effects of the two agents. With chloroform, the average time required is 4·8, with ethidene 4·4 minutes. The chloroform average is considerably augmented by four cases, in all of which the time occupied was more than twice, and in one case over three times the average. Deducting these four cases, the average will be found to be 4·1 in place of

4·8 minutes. There are only three cases in which the time occupied in recovery from ethidene was more than double the mean.

In two cases in which ethidene was employed, sickness during the operation is recorded. In one of these, this accident is accounted for by the fact that the patient shortly before the operation had taken a glass of milk. (The usual practice in the Western Infirmary is to allow the patient to have a cup of beef-tea five or six hours before the operation, and nothing after that time.) The sickness in the other case occurred as the patient was recovering from the anæsthetic. In twenty-four cases, sickness is recorded as occurring within twenty-four hours after the operation, in fifteen of which it was associated with more or less vomiting. In most of the cases the vomiting was slight; in three cases, however, it was severe. The average time during which the sickness and vomiting lasted, omitting one case in which it is questionable whether the vomiting was the result of the anæsthetic, was 3 hours 17 minutes in the twenty-two cases of sickness, and in the thirteen cases of vomiting the average is 4 hours 21 minutes. These averages are considerably increased by two cases in which sickness and vomiting lasted for twenty-four hours. If we take the mean of the time occupied in putting the patients who have suffered from vomiting and sickness under the anæsthetic, it will be noticed that it is 4·6 minutes, while the average dose of ethidene is 43·5 cc. Both of these, it will be observed, are a little above the general average. In two cases there was vomiting without sickness.

Let us now examine the condition of things in the cases in which chloroform was administered. In four cases we had vomiting during the operation; in three it was slight, in one severe. One of these cases was an out-patient, so there is some doubt as to the time when he last partook of food. It is a remarkable coincidence that as with ethidene so also with chloroform, there are twenty-four cases of sickness after the operation, and of these fourteen also suffered from vomiting, whilst one complained of vomiting without sickness. In two cases, the sickness was severe, in the others it was comparatively slight. The mean duration of the sickness was 10 hours, and of the vomiting 5 hours 50 minutes. The average time occupied in placing

these cases under the anæsthetic is 5·7 minutes, while the mean dose of chloroform is 33·5 cc., or 2 cc. per minute. As with ethidene, both of these are slightly above the average, but in neither case is this increase sufficiently regular, or of such an amount as to lead us to believe that the actual increase of the dose is in any way responsible for these symptoms; nor has the time during which the patient is under the anæsthetic any relation to them. Thus, in the case of ethidene, the mean is 24 minutes, as compared with 22 minutes in the cases all over, and with chloroform 17 as contrasted with 18 minutes.

The next point to which we desire to direct attention is one of considerable importance, and the only one in which there is much distinction between the action of the two anæsthetics, we have been considering, namely, *their influence upon the pulse-respiration ratio.*

Of the fifty cases in which ethidene was employed in only one instance did the pulse fall to 64 per minute, and the lowest number of respirations in the same time may be stated as 16. Both the pulse and respiration are particularly regular in a number of cases; as, for instance, in one where the mean number of respirations per minute is 18·2, the maximum 19, and the minimum 17; the pulse mean 83·2, the maximum 92, and the minimum 80 in the minute. With chloroform the results are somewhat different. In five cases the pulse fell to 64, in seven to 60, in five to 56, and in one to 48 per minute; and the respiration in five cases rose to between 30 and 35, in six to between 35 and 40, and in five to 40, or slightly above it—in one case to 72 per minute. With chloroform, as with ethidene, in some cases, there is particular regularity both in the pulse and respiration; as, for instance, in the case in which the pulse-respiration ratio is least altered the mean number of respirations per minute is 24·2, the maximum 26, and the minimum 23; the pulse mean 96·8, the maximum 108, and the minimum 92 per minute. The cases, however, are few in which chloroform does not produce a greater effect upon the pulse and respiration. In a certain class of cases the pulse-respiration ratio is greatly altered, the pulse falling as the respirations increase in frequency. With ethidine such cases are comparatively rare, and the changes observed are not so marked. Out of the cases in which chloroform was given

nine showed the changes to which we refer, whilst in only two of the ethidene were they seen, and even in these they were not very striking. The following charts show the comparative effects of ethidene and chloroform in this respect, the ethidene case selected as the most marked of the two, while the chloroform one is chosen as showing about the average of the nine cases above referred to.

. Take, first, the chloroform chart (fig 1). The normal line is

FIG. 1.

fixed a little lower than that of the ethidene (fig. 2), on account of the difference in the age of the patients—in one (chloroform) forty, in the other eleven years. The continuous lin shows the respiratory, the dotted line the pulse curve. The most striking feature in the chart (fig. 1) is the great rise in the respiration, and fall in the pulse from the normal

Shortly after the commencement of the administration of the chloroform there is a slight fall in the pulse (from 80 to 68), and respiration (from 18 to 16), followed by an increase from 68 to 80 in the former, and from 16 to 17 in the latter. For the next ten minutes there is a continuous fall in the pulse (to 48 per minute) and rise in the respiration (to 44 per minute). Within the next two minutes the pulse rises to

FIG 2.

the normal line, and the respirations fall to 32. This change corresponds with an interruption for four minutes in the administration of the anæsthetic. The subsequent administration of another dose of chloroform is followed by a similar though not so extensive alteration in the pulse-respiration ratio. It will be observed that the fall in the pulse is concomitant with the rise in the respiration. It is also to be noted that in those cases

where the pulse-respiration ratio is considerably altered the pulse shows a tendency to become dicrotic, so that a double impulse is communicated to the finger. Thus, a pulse where the beats only equalled 60 per minute might easily be mistaken for one where the impulses were 120 per minute. Associated with these changes we have also indications of low arterial tension.

Although the ethidene case is selected as being the one in which the pulse-respiration changes are most marked, yet there is a manifest difference as contrasted with the chloroform one. There is a gradual rise in the pulse for the first four minutes, followed by a gradual but almost continuous fall from 108 (at four minutes) to 68 (at twenty-two minutes), and succeeded by a slight rise corresponding with the stoppage of the administration.

The first rise in the pulse is in advance of a fall in the respiration, and the subsequent rise in the respiration is preceded by a diminution in the frequency of the pulse. After the fourteenth minute the respirations gradually rise to 26, and again fall to 25 before the administration of the ethidene is stopped.

Summary.—From the observations recorded above, we may draw the following conclusions:—

1. The dose (administered upon a towel) is greater with ethidene than with chloroform, but the time necessary to anæsthetise the patient is longer with the latter than with the former agent.

2. The number of cases of sickness and vomiting are about equal with the two agents, but the duration is considerably protracted in the case of chloroform. The occurrence of these symptoms have no relation to the length of time the patient has been under, or reference to the quantity of the anæsthetic administered in a given time.

3. With both agents the pulse-respiration ratio is considerably altered in a certain number of cases, the pulse falling as the respirations increase in frequency. With chloroform this change is not only much more marked, but also more frequent in occurrence than with ethidene, the proportion in our experience being nine of the former to two of the latter. There is also a greater tendency in the cases of chloroform to slowing of the heart's movements, and to dicrotism.

OBSERVATIONS ON THE TEMPERATURE OF THE HEALTHY HUMAN BODY IN VARIOUS CLIMATES.

By ROBERT PINKERTON, M.B. (Glasgow), *Member of the Order of the Medjidie.* (PLATE XII.)

WUNDERLICH, in his book on Temperature, says—"It is almost self-evident that our knowledge of the temperature of healthy human beings must be the basis of all our conclusions as to the temperatures met with in disease." In view of such a statement, it may not be out of place to give an account of some observations made by me on six perfectly healthy men during a voyage from this country to New Zealand.

The six men whose temperatures I have noted were, so far as careful investigation on my part enabled me to judge, perfectly healthy, and had good family histories. Their ages ranged from nineteen to forty-nine years. The observations were made by myself, and with every precaution to ensure accuracy. In fact, in order not to invalidate the results by attempting more than I was myself able to carry out thoroughly, I contented myself with one body temperature observation every 24 hours in each individual, taken as nearly as possible at the same hour and under the same conditions. For the same reason, the time of making the observations was fixed at 10 P.M., after the men were quiet in bed. The temperature of the air was taken twice a day, at 12 o'clock noon and at 10 P.M. I have noted in each case the age, occupation, birthplace, height, girth of chest, colour of hair, eyes, and complexion.

Name.	Age.	Occupation.	Native of	Height.	Girth of Chest.	Colour of Hair.	Eyes.	Complexion.
				ft. in.	in.			
1. MichaelGallocher	22	Farm labourer	Donegal	6 0¾	39¾	Brownish fair.	Grey	Fresh
2. William Andrew	21	Joiner	Caithness	5 9¾	40	Dark brown	Brown	Bright
3. Walter Fraser	40	Wood carver	Edinburgh	5 8¾	40	Fair	Grey	Light
4. Donald M'Hardy	49	Farmer	Aberdeen	5 8½	36½	Red	Light blue.	Ruddy
5. John Chapman	19	Engineer	Do.	5 6¾	38	Black	Dark brown	Dark
6. Donald Gun	19	Shepherd	Sutherland	5 9½	36½	Reddish fair	Dark blue	Fresh

The result of these six cases shows that the temperature of the healthy human body is not appreciably affected by either increase or diminution of the temperature of the surrounding atmosphere. In the cases under observation, the air temperature ranged from 56° to 85° F., a variation of 29°, and this variation, morever, took place twice during the time of observation, for we started with a low temperature, rose to a high one in the tropics, and gradually fell again as we approached the antipodes. We were fourteen days north of the tropics, during which the average temperature of the air was 68° F., then twenty days within the tropics, when the average air temperature was 81° F., and during forty-two days south of the tropics the average air temperature was 64·5° F. Two of the six cases under observation had temperatures ranging from 97° to 99·1° F.; one ranged from 97° to 99·3° F., one ranged from 96·4° to 99° F., one ranged 96·3° to 99·2° F., and one ranged from 96·2° to 99·1° F. The absolutely lowest body temperature recorded was 96·2° F., and the highest was 99·3° F., giving a range, therefore, of 3·1° F This is a greater range than Wunderlich gives, viz., from 97·25° to 99·5° F. In all the cases of extreme temperatures in my range I was careful to try at least two separate thermometers to check the observation. The thermometers were of the best description, and their accuracy certified by a certificate from the Observatory at Kew.

Sea-sickness occurred in two of the cases, and lasted in an ordinary form for two days, but did not affect the temperature of either. A curious point, taken in connection with Livingstone's observation that the temperature of Africans was 2° F. lower than his own, is, that the absolutely lowest temperature all through was exhibited by a dark haired and dark complexioned man.

Brown Séquard, in a journey from France to the Isle of France, took the temperatures of eight healthy people of ages ranging from seventeen to fifty-five years. Although his temperatures were taken under the tongue and mine in the axilla, the results may well be compared :—

Brown-Séquard's Cases.

With an atmospheric temp. of		46·4° F. showed a mean body temp. of			97·9° F.
8 days later,	,,	77°	,,	,,	99·4°
9 days later,	,,	85·1°	,,	,,	100·22°
6 weeks later,	,,	60·8°	,,	,,	99·04°

My Cases.

With an atmospheric temp. of		59° F. showed a mean body temp. of			97·46° F.
10 days later,	,,	75°	,,	,,	98·15°
10 days later,	,,	85°	,,	,,	98·16°
34 days later,	,,	56°	,,	,,	97·46°

An interesting point may be noticed in connection with No. 6, who suffered from a smart attack of measles during the voyage. The interpolation of the measles temperature in No. 6 temperature chart is most beautifully and characteristically marked (see Plate XII.) On night of 1st December his temperature showed a sudden rise to 103° F., next night it had fallen to 98·6° F. On night of 3d it had risen to 100·2° F., and on night of 4th to 102·4° F. The measles rash first showed itself on morning of 5th, and the temperature still continued to rise till it reached 105·2° F. that evening. It remained steady at 105·2° F. during night of 6th, but on 7th it had commenced to fall, and that evening it showed 102·4° F.; on night of 8th it only registered 101° F., and on 9th it was normal again, being 98·8°. There was thus exactly eight days during which the temperature was abnormal. The sudden rise of temperature at the beginning, followed by a return to normal, and then a rapid rise with the appearance of the rash and a continued rise of temperature, which, after reaching its maximum, remained steady at that point for two nights, and then falling to normal in three days, renders this case a most typical one.

ON THE LYMPHATICS OF CARTILAGE OR OF THE PERICHONDRIUM.

By GEORGE HOGGAN, M.B. (Edin.), and FRANCES ELIZABETH HOGGAN, M.D. (Zurich), M.K.Q.C.P. (Ireland). (PLATE XIII.)

THE structures described in the following pages have already formed the subject of a preliminary note announcing their discovery, which, by the great kindness of Professor Charles Robin, was presented in our name to the Académie des Sciences of Paris on the 4th July 1879, and afterwards published in full in the *Comptes Rendus* of the same date.

In several researches already published by us, which describe in detail the arrangements of the lymphatic system as it exists in relation to certain special tissues, we have adduced many facts and reasons which appeared fully to justify us in rejecting the theory of lymphatic radicles, Saftbahnen, or vasa serosa, formed by the branched cells of the connective tissue or the anastomosing cavities in which these cells are supposed to lie. We have further stated that our researches had forced upon us the conclusion that only an erroneous conception of the plan of the lymphatic system as a whole had led so many talented observers to presuppose the existence of definite channels within special tissues and organs, such, for example, as the glands of the skin and of the intestine, or inside the fibres of striated muscle, &c.

In those researches we have demonstrated that the commencements of the lymphatics were in general large collecting vessels, that in many cases they might, comparatively speaking, be called immense reservoirs into which there was simple transudation of the excess of lymph effused amongst surrounding tissue, and that as a rule, these collecting vessels or reservoirs were only found on the peripheral areas or surfaces either of the body itself or of its individual tissues and organs, acting there as the drainage adjuncts of those peripheral areas. From these superficial or peripheral collecting lymphatics the accumulated lymph is drawn off by the efferent lymphatics, those long moniliform or regularly valved lymphatics with which we have been so long familiar in preparations injected with mercury or in our general anatomical

text-books. It is these efferent lymphatics which lie in the deeper tissues and pass through the interiors or centres of special organs, carrying the lymph from the peripheral surfaces to pour it into the blood circulation near its centre.

These few preliminary remarks are necessary to explain the somewhat ambiguous title of this paper, for the lymphatics we are about to describe are functionally and physiologically the lymphatics of cartilage; that is to say, although they do not enter into its substance, but only lie upon its surface or pass through any perforations in the cartilage, forming, so to speak, anastomoses between the plexus of either surface when the cartilage is in the form of a sheet, they nevertheless drain off the lymph from the surface of the cartilage which has been exuded from the nutritive blood-vessels which nourish it, and so far are the draining adjuncts of the cartilage. On the other hand, these lymphatics lie embedded in the so-called fibrous tissue of the perichondrium, and therefore structurally and morphologically they are the lymphatics of that tissue; and as that tissue itself is only a nutritive adjunct of cartilage, we have chosen to describe these lymphatics as common to both. We may also make a preliminary remark with reference to our previous distinctions between collecting and efferent lymphatics. Following a rule pretty constant in the lymphatic system in different sized mammals, we find that while in the young or the very smallest mammals the peripheral plexus of lymphatics forms only one layer lying in one plane, and serving both as collecting and efferent lymphatics, yet as the size or age of the animal increases, so does the perichondrium increase in thickness, and the lymphatics being scattered throughout it, necessarily form a thick and intricate network; while, in addition, there is a special layer or arrangement of efferent lymphatics lying independent of the perichondrium which contains the collecting lymphatics, and these efferent lymphatics carry away the lymph which has been collected there.

As we claim to have discovered these lymphatics, it is hardly necessary for us to say that we have been unable to find out that any observers have ever described, or even looked for them. Albrecht Budge,[1] indeed, has described what he considers to be

[1] *Archiv für Microscopische Anatomie*, bd. xiv heft 1.

Saftbahnen passing between the cells of hyaline cartilage which he had been enabled to show by the injection of coloured material. It must be remarked, however, that not only have his conclusions and the appearances he described not been verified by subsequent investigators, but some of these of great eminence have stated that, although they had carefully repeated his experiments according to the instructions he gives, they had completely failed to obtain similar results, and they therefore reject his conclusions. We, on our part, have also endeavoured to verify his conclusions upon hyaline cartilage by our own special methods of using silver and gold solutions. Our preparations thus obtained have been perfectly clear and demonstrative, and had there been any channels, however small, in the cartilage, they would certainly have been shown by the silver. We have, however, found that in the outer portion of the cartilage, in that portion which it is difficult to distinguish from the perichondrium, in, therefore, the younger cell-capsules where the contained cells to the number of from four to eight were still multiplying, were, so to speak, in the embryonic condition, in a few cases the separate cells were sometimes connected to each other by delicate protoplasmic processes after the manner of the so-called branched cells of the connective-tissue. As soon, however, as the capsules had passed inside the periphery of the cartilage those processes no longer existed, and the individual cells within the capsules remained distinctly separate from each other, and unconnected either by actual processes of protoplasm or by any channel whatever to which the rôle of lymphatic radicle could be even hypothetically ascribed. We, therefore, in common with some of our more eminent fellow-workers, reject the conclusions of Budge, and consider the appearances he describes as the result of some accident, if not of some misinterpretation.

Apart from the foregoing, it is well known that there is a general concensus of opinion that cartilage possesses no lymphatics; and as for the perichondrium, we can only find one investigator who may be held to refer to it in an indirect manner, but to the effect that it possesses no lymphatics. In his *Vaisseaux Lymphatiques*, published in 1874, and therefore the latest work on the lymphatic system, Professor Sappey, after enumerating different fibrous tissues, such as the dura mater, the periosteum, &c.,

which (he states) possess no lymphatics, he concludes the sentence by saying (page 11), "toutes les parties fibreuses en un mot, sont privées de ce genre de vaisseaux." Without assuming that either periosteum or perichondrium are fibrous tissues, the above extract may be held sufficient to show that at so late a date, in the opinion of so eminent an observer as Professor Sappey, such structures as the perichondrium possessed no lymphatics. For the purposes of this research we have used only the methods of treating the tissues to be examined with solutions of silver and gold, our aim being not merely to demonstrate the existence of lymphatics, but to discover the relations they bear to the other tissues or cells of the parts; and for this purpose the method of injection would be entirely unsuitable. For the same reason, we have only used the tissues of the smaller mammals, as these tissues are generally thin and transparent enough to be examined under the microscope without undergoing the manipulations necessary to cut them into slices, and without the sources of error which those manipulations too often cause. One other great advantage is obtained by using the smaller mammals, inasmuch as the lymphatics being few and generally upon or within a thin plane, we are thus enabled to arrive at a true conception of the plan of the lymphatics, which is generally obscured in the large mammals by the great number and complexity of the lymphatics in certain localities which we may wish to investigate.

We have specially directed our attention to the lymphatics of the costal and ensiform cartilages as representing the hyaline variety, and to those of the auricle as representing yellow elastic cartilage. With regard to these different cartilages, when in the embryonic condition, it need only be mentioned that, as the lymphatics lie in all cases in the perichondrium, the difference between them in the embryonic and adult conditions is merely one of increased number, size, and development, there being no difference in the plan in any case. It is also true that the cartilage of the ear of the mouse is called embryonic cartilage, although in larger mammals it is called yellow-elastic cartilage. There is, however, except in number and size, no difference whatever in the plan or arrangement of the lymphatics in the ear cartilages of different mammals. As a matter of fact, it is entirely

incorrect to speak of the one cartilage as being of a different kind compared with the others. It is merely a question of the amount of intercellular substance in each, which varies according to age or size, but has no other distinction, and least of all in the arrangement of the lymphatic, which is at present our main affair.

In order to demonstrate the lymphatics of the costal and ensiform cartilages, no animal could be more suitable or convenient than an ordinary house mouse or young rat. It is, however, imperatively necessary that the animal should be absolutely lean or devoid of fat cells, as if the latter are present it is impossible, under any circumstances, to demonstrate the lymphatics by the silver method. To prevent our object from being defeated by the extravasation of blood upon the tissues we wish to examine, the animal ought not to be roughly handled, but gently destroyed with chloroform. After it is insensible, the head ought to be snipped off, so as to get rid of all the blood in its body. This having been effected, the skin is stripped off the thoracic wall, and the pectoral muscles must also be cleaned off the outer surface of the thoracic wall with a sharp scalpel or pair of fine-pointed forceps, so as to leave the costal cartilages and sternum quite bare and clean. The abdominal muscles are next separated from the thoracic wall, and the liver and diaphragm are also snipped off with fine scissors, taking care not to injure the ensiform cartilage in so doing. The lungs, which will be now observed to be lying collapsed at the back of the thoracic cavity, are to be carefully removed along with the heart, so as to leave the internal surfaces of the costal cartilage near their junction with the ribs clean and untouched. A 1 per cent. solution of nitrate of silver is now poured quickly within the thoracic cavity and upon the ensiform cartilage, and poured off again as quickly as possible, without allowing the solution to touch the outer surface of the thoracic cage, which would only serve to make the preparation less transparent by being treated on both surfaces with silver. After a few minutes exposure to a dull light, the whole may now be washed for the first time with distilled water, and a few drops of a 1 per cent. solution of chloride of gold be allowed to remain in contact with the silvered surface for a few minutes,

and afterwards washed off very thoroughly. The structures must now be clarified by glycerine before they are in any way excised, and great care is necessary at this stage to use at first glycerine largely diluted with water, but concentrating it gradually till only pure glycerine is used. In this way the distortion of the parts which would otherwise happen is entirely avoided, and when the preparation is rendered quite transparent the whole of the front wall of the thoracic cage may be clipped out external to the junction of the cartilage with the ribs, and the preparation examined under the microscope.

At this point an important caution may be given. The animal may have been perfectly suitable, the instructions carefully followed, and the lymphatics, irregular at all times both as to presence or distribution, may exist in perfection, and yet in a very large percentage of cases the operator may fail to demonstrate them. This is due to the fact that the solution has not penetrated sufficiently far, or it may be too far, to display the lymphatics. There is a point at which it saturates the tissues immediately surrounding the lymphatics without saturating the lymphatics themselves. In this case the lymphatics, with their crenated endothelium, show white in a purple matrix. Anything either short of or beyond that point will lead to failure. As a rule, the silver solution cannot remain too short a time in contact with the tissue; for the rest practice and patience will lead nearest to perfection.

If the preparation is not successful, try another; if it is a success, seal it up in glycerine in the following manner. Place the preparation on a clean glass slide. Take a cover glass of considerable thickness and strength which extends as far as possible beyond the tissue on every side, while it is narrower than the glass slide itself. Next cut a small piece of flat wood or bit of glass a little larger than the tissue, but smaller than the cover glass, and glycerine having been sufficiently interposed, clamp the slide, tissue, cover glass and guard together with an ordinary paper clip, which will flatten the preparation without injuring its surface. Wipe now the excess of glycerine carefully from the edge of the cover, and from a stick of burning sealing-wax let a few drops fall round the margin of the cover glass, and trim the whole smoothly with a hot iron wire, taking care

not to heat the slide unequally, lest it should break. In this way an excellent permanent preparation is obtained, and may be examined as necessary. We make no apology for stating the foregoing method at such length, it being entirely the fruit of our own experience, and fulfilling a desideratum much wanted and but little known, as well as being an indispensable adjunct to our special methods of preparing such tissues.

While studying the lymphatics on the pleural surface of the thoracic muscles, we had often observed that, lying upon the portion of the internal or pleural surface of the costal cartilage intervening between the attachments of the triangularis sterni, on the one hand, and the junction of the cartilage with the ribs, on the other hand, the lymphatics were generally plentiful, even when they could not be demonstrated on the neighbouring tissues. In fig. 3 *a*, we show such a plexus lying upon the inner surface of a costal cartilage in the mouse; and it will be observed that, while it stops externally (in relation to the mesial plane) at the junction *e* of the cartilage *c* with the rib *d*, it is prolonged superiorly, inferiorly, and internally at *b*, upon the pleural surface of the triangularis sterni muscle *f*, in the form of the rectangular meshed or gridiron plexus characteristic of the lymphatics of striated muscle which we were the first to describe. For a long time we hesitated to describe these as the lymphatics of the perichondrium, for it might fairly be argued that they were quite as much the lymphatics of the pleura as of the perichondrium. At that time we did not know, as we afterwards discovered to be the case, that while in man the comparatively thick pleural membrane possesses special lymphatics as well as blood-vessels of extremely irregular character, and which ramify through it entirely independent of and uninfluenced in arrangement by the intercostal spaces, in the smaller mammals, on the contrary, the serous membranes possess no special lymphatics, but are dependent for these, as for nutritive blood-vessels, upon the tissues upon which they lie. In such cases the lymphatics retain the form or arrangement given to them by their special tissues; and thus we find that, while the plexus under consideration is extremely irregular where it lies upon or in the perichondrium, it at once assumes the rectangular meshes when it passes upon the fibres of striated muscle, showing that

its shape is modified not by the pleura which lies superficial to it, but by the deeper tissues which upon it lies, and to which therefore it properly pertains. It might be imagined that, by similarly preparing the outer surface of the cartilages, the matter would be set at rest; but, unfortunately, the tissues lying upon that surface are too thick to allow the lymphatics to be shown, and any attempt to remove these tissues would completely destroy any lymphatics that might exist there.

The walls of the irregularly arranged lymphatics lying in the perichondrium are formed solely of the one layer of the crenated edged endothelium characteristic of the lymphatic system, while the meshes between these lymphatics are filled up principally by branched cells, probably wandering cells, lying in a scanty gelatinous matrix. These branched cells have no special connection with the lymphatics, although many people would be inclined hypothetically to consider them to be the radicles of the lymphatics in question.

When such a preparation is viewed under the microscope, the following structures come in focal order: first the straight-edged endothelium of the pleura; next the thin gelatinous layer of that membrane; then the crenated endothelium of the lymphatics, and the branched cells lying in the meshes between them; finally the outer cells of the cartilage, often branched at first, but becoming globular as we pass toward the centre of the cartilage,—both lymphatics and cells appearing white in the purple matrix, formed partly of cartilage, partly of gelatinous tissue. The lymphatics of the plexus seen in fig. 3 are only the collecting vessels; they become connected with the efferent lymphatics through the substance of the triangularis sterni muscle, and these efferent vessels lie between that muscle and the intercostal muscles until they reach the edge of the former, after which they lie in the intercostal spaces parallel to the ribs, and immediately underneath the pleura, these efferent lymphatics being common to all the lymphatics of the locality.

Perhaps one of the greatest obstacles to our considering the foregoing lymphatics as those of the cartilages lay in the fact, that for a very long time we completely failed to show by our usual methods the existence of lymphatics upon the ensiform

cartilage. In the smaller mammals, this structure is remarkably broad and thin, and being in a manner isolated from all other tissues except the peritoneum, it ought to have formed an excellent material for preparations. Latterly, however, by a happy chance, while applying our methods upon a very lean animal, we succeeded in demonstrating clearly a wonderfully plentiful supply of lymphatics lying on both surfaces of the cartilage, and it became evident to us that the cause of our failure hitherto lay in the presence of a thick layer of fat cells between the peritoneal surface and the perichondrium in which the vessels lay, a fact, however, which was of great importance in proving that the lymphatics belonged solely to the cartilage, and had no connection with the peritoneum. Once that we had discovered the cause of our previous failures, we had no difficulty afterwards in demonstrating the lymphatics of this part; for even when the animal was well nourished and the lobules of fat cells abundant upon the cartilage, yet the connection of these lobules with the other structures was so very loose that the fat layer could be removed with fine-pointed forceps from the surface of the sheet of lymphatics without in any way damaging those vessels, which could be demonstrated afterwards in whole or in part by the process we have described.

In order, however, to show the complete plexus, it is always necessary to choose a very lean animal, and some of our best preparations were made upon the ensiform cartilages of young rats only one or two days old, for however well nourished the mothers may have been, we generally find that fat does not begin to develop in this locality in the young until after the period we have mentioned; and, moreover, at this time the lymphatics are undergoing rapid development, which enables us more easily to seize the plan of their formation. In such specimens we find the lymphatics develop from above downwards as an irregular arch lying parallel to the edge of the cartilage, but some little distance back from that edge. The pillars of the arch are formed by one or more lymphatics on either side of the mesial line, which are afterwards the special efferent lymphatics of the part, as shown in *a*, fig. 2, from the anterior surface of the cartilage of an adult rat. From the zigzag arched vessel thus formed branches are developed at the angular bends, which pass towards

the centre, bifurcate, and join again with neighbouring branches so as to form the very irregular plexus shown in fig. 2.

Nor is their course more irregular than their shape and size. Small narrow lymphatics suddenly become dilated into great pouches, which deserve the name of lymphatic sacs, and again contract as suddenly into narrow channels. Here also, as elsewhere, the lymphatics bear no regular relationship to the blood-vessels, which ramify quite independently amongst the tissues of the part, as shown in fig. 5 *b*—a much more highly magnified view of the same lymphatics from the posterior surface of the cartilage in a young rat. The description given of the structure of the lymphatics of the costal cartilages applies equally well to those now under consideration, the meshes between them being also largely occupied by branched cells *cc*, which readily develop fat within them, and become the fat cells *dd*, that finally succeed so thoroughly in hiding the lymphatics *aa*, in fairly nourished animals.

In fig. 2 only a portion of the lymphatics on the anterior surface is shown under a low power, as the lymphatics of the whole surface could not well be brought within one field of the microscope. The plexus is not, however, equally dense over all the surface, there being a narrow peripheral zone near the edge unprovided with lymphatics, or upon which only a short branch passes here and there from the main plexus towards the edge on either surface; but it seldom reaches the very edge, and in no case have we ever found any anastomosis taking place at the edge between the lymphatics on the anterior and posterior surfaces; and there are no perforations in the cartilaginous sheet (as in the case of the auricle) through which anastomosis between them could be effected. These lymphatics are, as a rule, provided with valves where they bifurcate or join each other, but the size of these valves, and the distances between them, are quite as irregular as the size and form of the lymphatics in which they are found.

The value of the fat cells interposed between the peritoneum and the cartilage, as a diagnostic element for proving that the lymphatics only belong to the latter structure, is very evident. Although in lean animals the peritoneum may lie close upon the lymphatic plexus, the development of a layer of fat, equal in thickness to

the cartilage itself between the perichondrium and its lymphatics on the one hand, and the peritoneum on the other, tends to lift the latter up or away from the lymphatics. The further fact, that when silver is applied to the peritoneal surface it makes the markings of the serous endothelium and of the subjacent fat cells distinct, without showing any trace of lymphatics or connection between them and the peritoneum, goes to prove that the lymphatics in question belong only to the perichondrium; for, owing to the transitory character of the fat cells and the isolated condition of the cartilage, the lymphatics cannot be ascribed to any other tissue whatsoever.

We pass next to the lymphatics of yellow elastic cartilage, to show which we choose the cartilage of the auricle, on account of its isolated and accessible condition. In order to prepare this tructure, it is necessary to strip the skin off carefully, so that we may be able to apply the reacting solutions directly upon the perichondrium. To do this it is preferable to begin with the posterior surface, for there the skin is loose and easily removed, and the lymphatics most abundant. An incision is first made in the antero-posterior direction through the skin at the root of the auricle with a pair of fine-pointed scissors, and two incisions are then made at right angles to the first one by pushing the point of the scissors between skin and cartilage in the direction of the borders of the auricle. It is now easy to drag the skin off the auricle (which is still attached to the head), helping it by snipping through any small nerve or bit of tissue that may appear to bind skin and cartilage together. When the skin has been stripped off to the very tip it should still be left attached to the tip; and the auricle being then cut off near its attachment, the two tissues are pinned down with small pins inserted near its edges upon a piece of cork, leaving the bared surface of both auricle and skin uppermost and untouched, while it lies stretched upon the slab of cork. Upon this surface the re-agents and clarifying fluids are to be applied according to the instructions already given, and if successful—and it generally is successful—the tissue may be put up as a permanent preparation. Indeed, we may here remark, that we know no tissue or locality in the whole body where the lymphatics can be shown so beautifully or with such certainty; for out of above a hundred specimens

we have never missed one preparation, and that ratio is sometimes reversed in seeking for the lymphatics of some other localities or tissues, this success being probably due to the general absence of fat cells from the subcutaneous tissue of the skin covering the auricle. The utility of leaving the skin attached is to make it clearly evident that the lymphatics seen lying upon the cartilage are certainly not the lymphatics of the skin, for the two structures, being prepared at the same time, show their respective lymphatics equally well, and their exact relations to each other can also be verified at any time; and, indeed, we may even remark here that it is impossible to get a better demonstration of the collecting lymphatics of the skin, and their relations to its appendages, than that which is given in such a preparation.

The arrangement and amount of the lymphatics in this locality are greatly influenced by the size of the animal. In the mouse they are comparatively few, and the collecting lymphatics of skin and cartilage serve, to a certain extent, as efferent vessels for the respective sides. In the rat, however, we find the efferent lymphatics coming in as a third layer between the collecting sheets of lymphatics for the skin and cartilage respectively, and being common to both in their efferent functions. These accompany the posterior auricular vessels and nerves, and unless special care be exercised these vessels may be left either upon the cartilage or skin-flap. In fig. 1 we have a view, under a very low power, of the arrangement of the lymphatics *aa*, on the posterior surface of the cartilage of the ear of a rat, and their relationship, or rather want of relationship, to the posterior auricular vessels and nerves. As these latter structures lie close together and parallel to each other, only the arteries *bb*, are shown in the drawing in order to avoid confusion. Fig 4, again, shows, under a much higher power, a portion of the lymphatic plexus lying near the root of the auricle of a rat, in which locality it is much denser than elsewhere, and the vessels themselves much larger and dilated. In the same preparation the relation of the blood-vessels and capillaries of the part to the lymphatics, and their small size, as compared to these immensely dilated lymphatics, are well seen. In the auricle of the mouse, as shown in fig. 6, the lymphatics *aa*, are much more scanty,

but for that same reason it is easier to determine the plan of their formation. In this case, also, the tissue of the perichondrium is so extremely thin, that the cells of the cartilage itself take on the markings resulting from the application of the silver solution, so as to show the exact relations of the cartilage and its cells *d*, to the lymphatics *aa*.

There is a feature of special interest in the structure of the cartilage of the auricle, which has an important bearing upon the character and distribution of the lymphatics of the part, and in proving beyond dispute that these are the lymphatics of the cartilage proper. This feature consists of the presence of a large number of circular holes perforating the cartilage, and giving to it a cribriform character, as seen in *bb*, fig. 6. Through these holes the lymphatics of the one surface form so complete an anastomosis with those of the other surface as to make us look upon the lymphatics of the two surfaces as forming only one plexus, the communication between them being as frequent as if the lymphatics lay actually within the cartilage, that tissue lying, as it were, within the lymphatic meshes. These holes also give passage to nervous and arterial twigs occasionally, but the lymphatics are evidently the structures they are specially adapted for; and as they are much larger than those vessels (at all events in the collapsed condition), the remainder of the lumen is filled up with fat cells and branched cells. On the anterior surface of the cartilage the lymphatics present pretty much the same appearance as those shown in fig. 6, this enlacement being apparently adapted to the requirements of the part, as there is little provision for efferent lymphatics on the anterior surface of the cartilage. When the skin is carefully removed from the anterior surface, these lymphatics are easily made apparent; but, at the same time, it is a matter of considerable difficulty to remove it, on account of its intimate adhesions to the perichondrium of that surface, so that as often as not the perichondrium becomes stripped off the cartilage along with the skin. We have already mentioned that in the case of rats and larger mammals we have the main chain of efferent lymphatics lying between the posterior surface of the cartilage and the skin, along with the posterior auricular vessels and nerves; and these efferent lymphatics seem to serve as drainage adjuncts for the

collecting lymphatics of skin and cartilage of both surfaces. While, however, the collecting lymphatics of the skin on both surfaces are continuous round the edges or tip of the auricle, we do not find the lymphatics of both surfaces of the cartilage anastomosing over the edges of the cartilage in a similar manner. They never pass beyond the holes formed near the extreme border of the cartilage through which they pass and form the terminal enlacements of the plexus. The only exceptions to this rule are merely apparent, and are due to the fact that the ordinary hole, in consequence of the absence of material at its external side, forms a notch through or round which a lymphatic may be seen to pass.

Another peculiar feature in the auricle is the presence of innumerable small bundles of striated muscle, microscopical in size, which pass in every conceivable direction from one part of the auricle to another, and are attached at both extremities to the perichondrium. These are seen at *cc*, figs. 4 and 6. In the latter preparation they were especially small, consisting at times of two or three fibres only, which were so short that they appeared like elongated cells. Amongst these bundles the lymphatics of the part ramify in every possible direction, sometimes superficial to them, sometimes between them and the cartilage, and at other times ramifying in their substance, in which position they might almost be held to belong more to the muscle than to the cartilage. They never showed, however, the peculiar rectangular meshes, or gridiron plexus, that seems to be the special form of the lymphatics of striated muscle. In rats and the larger mammals, the lymphatics which lie in the spaces between the attachments of the extrinsic muscles of the auricle are very much larger, and form a denser plexus than elsewhere, as shown in fig. 4. This dilated condition of the lymphatics at those localities probably subserves some function which we have not as yet been able to find out.

Here, as elsewhere throughout the body, the lymphatics bear no relation whatever to the blood-vessels or nerves of the part, either as regards position or relative amount. As in the specially isolated cartilages which we have described, the lymphatics in the perichondrium seem to be equally plentiful and equally irregular in distribution, it may be taken for granted

that similar conditions exist in the less isolated cartilages throughout the body, upon which the silver method of preparation could not conveniently be applied. For the same reason, although the silver method cannot well be applied to the same tissues in the case of man and the larger mammals, on account of their great thickness and the destruction that would ensue to the lymphatics in any attempt to make sections, yet the general relationship of the lymphatic system, as found relatively in small and large mammals, which our previous researches have enabled us to understand, warrant us in saying that if the injection method be applied, the lymphatics will be found to exist in the perichondrium of larger mammals as a dense complicated plexus, too intricate to enable us to recognise the plan of distribution as we can recognise it in the smaller mammals, but to which the researches we now put on record form the certain key.

Previous researches on the lymphatics referred to in the preceding pages:—

1*st.* Étude sur les lymphatiques de la peau. *Journal d'Anatomie*, Paris, January 1879.

2*d.* Étude sur les lymphatiques des muscles striés. *Ibid*, November 1879.

3*d.* On the condition of the lymphatics in Eastern leprosy. *Transactions of the Pathological Society of London*, 1879.

4*td.* Étude sar le rôle des lymphatiques de la peau dans l'infection cancéreuse. *Archives de Physiologie*, Paris 188, p. 284.

Description of Plate XIII.

(Drawings made by the aid of the Camera Lucida.)

Fig. 1. Lymphatics of the posterior surface of the cartilage of the auricle, under a very low power, in an adult rat.—*aa*, lymphatics; *bb*, arteries to which correspond also the nerves and veins; *c*, one of the perforations in the cartilage through which pass the peripheral enlacements of the lymphatic plexus ($\frac{1}{18}$).

Fig. 2. Lymphatics of the anterior surface of the ensiform cartilage, under a low power, in an adult rat.—*aa*, efferent lymphatics; *cc*,

collecting lymphatics; *b*, interval in mesial line between attachment of rectus thoracis muscles ($\frac{1}{18}$).

Fig. 3. Lymphatics on posterior surface of costal cartilage in an adult mouse.—*a*, lymphatics of cartilage; *bb*, lymphatics of striated muscle forming part of the same plexus; *c*, costal cartilage; *d*, end of rib; *e*, joint between cartilage and rib; *f*, fibres of triangularis sterni muscle ($\frac{1}{90}$).

Fig. 4. Dense plexus of large lymphatics on posterior surface of the cartilage of the auricle in an adult rat.—*aa*, lymphatics; *bb*, blood-vessels; *cc*, fibres of striated muscle; *dd*, branched cells of the perichondrium ($\frac{1}{100}$).

Fig. 5. Lymphatics on the posterior surface of ensiform cartilage, under a high power, in the rat.—*aa*, lymphatics; *bb*, blood-vessels; *cc*, branched cells of perichondrium; *dd*, fat cells developing from the afore-mentioned branched cells ($\frac{1}{180}$).

Fig. 6. Lymphatics on the posterior surface of the cartilage of the auricle in the mouse.—*aa*, lymphatics; *bb*, holes perforating the cartilaginous sheet through which pass the lymphatics to anastomose with those of the anterior surface, and containing fat cells; *cc*, striated muscle fibres; *dd*, cells of cartilage ($\frac{1}{100}$).

A PALATINE BRANCH FROM THE MIDDLE MENINGEAL ARTERY. By R. J. ANDERSON, M.D., *Demonstrator of Anatomy, Queen's College, Belfast.*

In a Male Subject.—The following arrangement obtains on the right side of the head and neck. The superior thyroid arises one quarter of an inch from the origin of the carotid. The lingual and facial arise by a common trunk three-quarters of an inch in length; the latter gives off the inferior palatine. The *ascending pharyngeal* comes from the posterior surface of the carotid close to its origin. An *accessory pharyngeal* is derived from the external carotid (posterior surface) close to the origin of the facial-lingual trunk. The internal maxillary gives off the tympanic and middle meningeal, the latter the small meningeal; the other arteries are normal in distribution and relations.

On the left side, the common carotid divides in the usual place. The following is the arrangement of the branches of the external carotid:—The lingual arises one inch from the bifurcation. The facial comes from the external carotid one-eighth of an inch higher than the lingual, and gives off the inferior palatine, which passes in between the stylo-glossus and stylo-pharyngeus; before the passage of the artery through the space indicated, it gives off a tonsilar. The

superior thyroid arises close to the origin. The occipital is derived from the external carotid, at a distance of one inch from its origin, and immediately afterwards gives off an *accessory pharyngeal* artery, which first passes upwards between the external carotid and occipital, then lying on the internal carotid it passes with this artery beneath the stylo-pharyngeus, stylo-glossus, and posterior auricular artery, and finally enters the carotid canal. This artery, near its origin from the occipital, gives off a pharyngeal branch that passes downwards beneath the external carotid, facial and lingual arteries, and enters the middle constrictor, an inch higher up a meningeal branch, which goes through the jugular foramen; and finally, before entering the carotid canal, it gives branches to the superior constrictor, and a long branch that enters the internal pterygoid muscle near its posterior (outer) extremity. The sterno mastoid artery is derived from the occipital. The *ascending pharyngeal* arises from the external carotid close to its origin, passes upwards on the inner side of the internal carotid, and distributes branches to the pharynx and anterior spinal muscles. A meningeal branch also is given off by this artery, which goes through the foramen lacerum medius, and finally a palatine branch.

The internal maxillary artery arises below the condyle of the lower jaw, and passes forwards and inwards over the external pterygoid. The tympanic arises from the external carotid, and ascends to the Glaserian fissure.

The middle meningeal arises from the internal maxillary, and passes upwards to the foramen spinosum. Three lines from its origin it gives off a branch, whose calibre is nearly equal to that of the continuation of the meningeal. Derived in this way from the middle meningeal, this artery passes downwards beneath the internal pterygoid between this muscle and the superior constrictor, turns round the border of the tensor palate, and divides into two branches, one of which (the upper) is distributed to the soft palate, the other to the pharynx. This artery gives off the small meningeal at a distance of one line from its origin. The small meningeal, before its passage through the foramen ovale, distributes some small twigs to the external pterygoid, and gives off a branch of more considerable size that anastomoses with a branch of the palatine artery. Near the tensor palate, the palatine artery gives off a branch that passes upwards in relation with the internal pterygoid, then comes into contact with the tensor palate, and divides into two branches, one of which, after giving off small muscular branches to the tensor palate near its origin, breaks up into small twigs that enter the external pterygoid plate; the other branch gives also some muscular twigs to the tensor palate, and finally perforates the sphenoid above the scaphoid fossa; before entering the sphenoid, a communication takes place between this artery and the small meningeal. Of the two terminal branches of the upper part of the palatine artery, one passes along the free, the other along the attached border of the soft palate.

The inferior dental artery arises from the first part of the internal maxillary, and gives off the mylo-hyoid branch. In the second stage,

the anterior and posterior temporal, buccal, and masseteric arteries are given off. The posterior dental and infraorbital arise by a common trunk from this portion of the internal maxillary—a not unusual variety. In the third stage, the internal maxillary gives off the descending palatine, and divides into three branches for the nose, pterygo-palatine and vidian foramina.

Many of the anomalies recorded above are frequent. The occasional presence of an accessory pharyngeal artery is recorded by Mr Quain,[1] Weber,[2] and other anatomists. A branch of the ascending pharyngeal that passes through the carotid foramen and supplies the dura mater near the sella turcica or the wall of the cavernous sinus, has been mentioned by Quain and Hyrtl.[3] The large branch of the accessory pharyngeal artery to the lower and anterior part of the middle constrictor seems unusual; a laryngeal branch of the ascending pharnygeal is mentioned by Hildebrandt.[3] The internal pterygoid branch of the accessory pharyngeal artery above noted seems of interest.

The middle meningeal has been seen to give off an artery to the tongue, which divided into sublingual and dorsal lingual.[3] The origin of a palatine artery from the middle meningeal is unusual, and if taken in connection with the fact that a branch of considerable size enters the body of the sphenoid, would seem of more than ordinary interest. That branches of the pharyngeal arteries should supply the sphenoid bone is to be expected; and from the known facts with reference to the development of the pituitary body, and the connection of the anterior part with the pharynx at one period, the arterial supply of the continuous structure is probably derived from the same source when the anterior part is united with the pharynx. As the body of the sphenoid becomes filled up, the connection of the hypophysis (anterior lobe) with the pharynx becomes narrower, and finally the parts are separated, the former joining the infundibulum. The vascular supply from the pharyngeal source ceases partially or entirely, and becomes replaced in part or altogether by an intracranial supply. In one case recorded by W. Müller,[4] an artery (presumably) from the pharyngeal was found coming from the body of the sphenoid and entering the pituitary body. A foramen cavernosum ossis sphenoidei for the vena vertebralis mediana is present in the rabbit (W. Krause).[5] The palatine artery described above may be supposed to represent an original palato-maxillary artery, and supply the process of that name, the pharynx and the hypophysis. The change that resulted from the further development of the parts left the major portion of the artery supplying the palate and the pharynx, whilst another portion, viz., that which supplied the hypophysis, remained as a branch entering the body of the sphenoid.

[1] *Arteries*, p. 110 (8 cases in 144).
[2] Hildebrandt's *Anatomie*, vol. iii. 361.
[3] W. Krause, in Henle's *Handbuch der Gafässlehre*, p. 251.
[4] *Jenaische Zeitschrift*, 1871, referred to by Henle, *op. cit.* p. 251.
[5] *Allgemeine und microscopische Anatomie*, p. 437.

MUSCULAR ANOMALIES. By J. F. Knott.

The following are among the most remarkable of the anomalies in human myology which came under my notice in the dissecting room of the Royal College of Surgeons, Dublin, during 1879–80:—

Radio-carpus (Fano). Radialis internus brevis *v.* minor (Gruber) = Flexor carpi radialis brevis *v.* profundus (Wood).

A very good specimen of this muscle was found in the left fore-arm of a tall muscular subject. The origin was from the anterior surface of the radius from the level of the lower end of the oblique line to about an inch and half above the lower end of the bone. Its position was external to the flexor longus pollicis and pronator quadratus. The fibres passed downwards and slightly inwards and formed a small round tendon which passed through the anterior annular ligament in a separate canal on the outer side of that for the tendon of flexor carpi radialis. Its insertion was by two slips, the larger into the base of the 2nd metacarpal bone outside the tendon of the flexor carpi radialis and partly blended with the latter, while the smaller turned obliquely inwards to be inserted into the front of the base of the 3rd metacarpal. This muscle, which was first described by Fano (*Bull. de la Société Anat. de Paris*, Nov. 1851), and afterwards by Prof. W. Gruber and others, has been found by Prof. Macalister and Mr Wood fifteen times in 283 subjects, making an average frequency of nearly one in 19. I specially examined 34 subjects without finding another example.

Levator Claviculæ (Wood).—Two specimens were observed. One arose from the posterior tubercles of the transverse processes of the 3rd and 4th cervical vertebræ, and was inserted into the middle part of the upper border of the clavicle, in the interval between the trapezius and sterno-cleido-mastoid. The other arose from the transverse process of the 6th cervical vertebra, while its insertion was blended with the inner part of the clavicular insertion of the trapezius on its posterior aspect.

Supra Clavicularis Proprius v. *Tensor Fasciæ Colli* (Gruber).—Of this very rare muscle I have found one example. The inner end was attached in front of the clavicular head of the sterno-cleido-mastoid about an inch and three-quarters outside the sterno-clavicular articulation, while the outer extremity, at a distance of about wo inches from the acromial end of the clavicle, had a somewhat broader attachment in front of the trapezius. The muscle between its points of attachment formed a slight curve with the convexity upwards, and was enclosed and fixed in its position in a sheath formed by the deep cervical fascia. Short tendinous fibres attached it to the bone at either end; the remainder of its length was fleshy, with a few bundles of white fibres here and there prolonged from the tendons.

Chondro-epitrochlearis (Wood, Macalister).—One example was observed. The attachments were similar to those of the chondro-epitrochlearis described by Prof. Macalister. Arising by fleshy fibres

from the cartilage of the sixth rib on the right side, in close connection with the lower border of the pectoralis major, it followed the course of the lower border of that muscle till it reached the inner side of the arm, and then turned downwards on the inner aspect of the limb, forming a narrow flattened tendon which blended with the brachial aponeurosis immediately above and in front of the epitrochlea.

Sterno-cleido-mastoid.—Numerous minor variations were seen. In several cases the sterno-mastoid and cleido-mastoid were completely separate from origin to insertion, and in one the spinal accessory nerve passed between the two parts. In another case, besides the entire separation of the two parts of the muscle, the cleido-mastoid was in its turn subdivided into two parallel planes of muscular fibres (a superficial and a deep), with a thin layer of fat and connective tissue between. This is, at least so far as I can ascertain, a condition rarely observed; but examples have been recorded by G. Meckel and by Professor Macalister.

Pterygoideus proprius (Henle).—Of this muscle I have met with three examples. In each instance it was attached by one end to the crest on the great wing of the sphenoid, and by the other to the posterior border of the external pterygoid plate. Of the rarer form described by Prof. Macalister, where the inferior extremity is attached to the tuber maxillare, I have observed one example only.

Transversus nuchæ (F. E. Schultze).—Two well-marked examples, with similar attachments, were seen. Passing from the external occipital protuberance and inner end of superior curved line, for about half an inch, the fibres proceeded horizontally outwards to blend with the tendinous insertion of sterno-cleido-mastoid at the outer end of the superior curved line and base of mastoid process. According to Prof. Macalister, this muscle is always symmetrical. I found it so in one of my examples; in the other, the opposite side had been already dissected, and I was not able to find out whether the muscle had been present.

Omo-hyoid.—In one instance I found the anterior belly of this muscle represented purely by tendon. In another case the origin of the muscle was solely from the base of the coracoid process. This peculiar form of the muscle has been described by Gruber under the name of coraco-hyoid. An additional origin from the clavicle was found in several instances, but a purely clavicular origin I have not had an opportunity of observing.

Stylo-hyoid.—Complete absence of this muscle was observed in one instance. Two examples of doubling of the muscle were met with, the duplicate arising in one instance from the base of the styloid process, as in the case recorded by Lawson Tait (*Jour. Anat.*, iv. 237); in the second example the origin was close to the apex.

Quadratus femoris.—Complete absence of this muscle was observed in one instance.

Peroneus quartus (Otto) v. *Sextus* (Macalister).—One well-marked example of this muscle was met with. The origin was blended with the lower fibres of attachment of the peroneus brevis; the insertion was into an elevation on the outer surface of the os calcis, about a quarter of an inch behind the peroneal tubercle.

PLATE II

BOVINE TUBERCULOSIS IN MAN.

R Farren Del.

Vincent Brooks Day & Son Lith

Plate III

BOVINE TUBERCULOSIS IN MAN

7

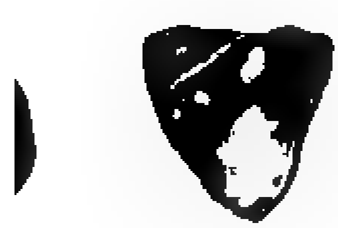

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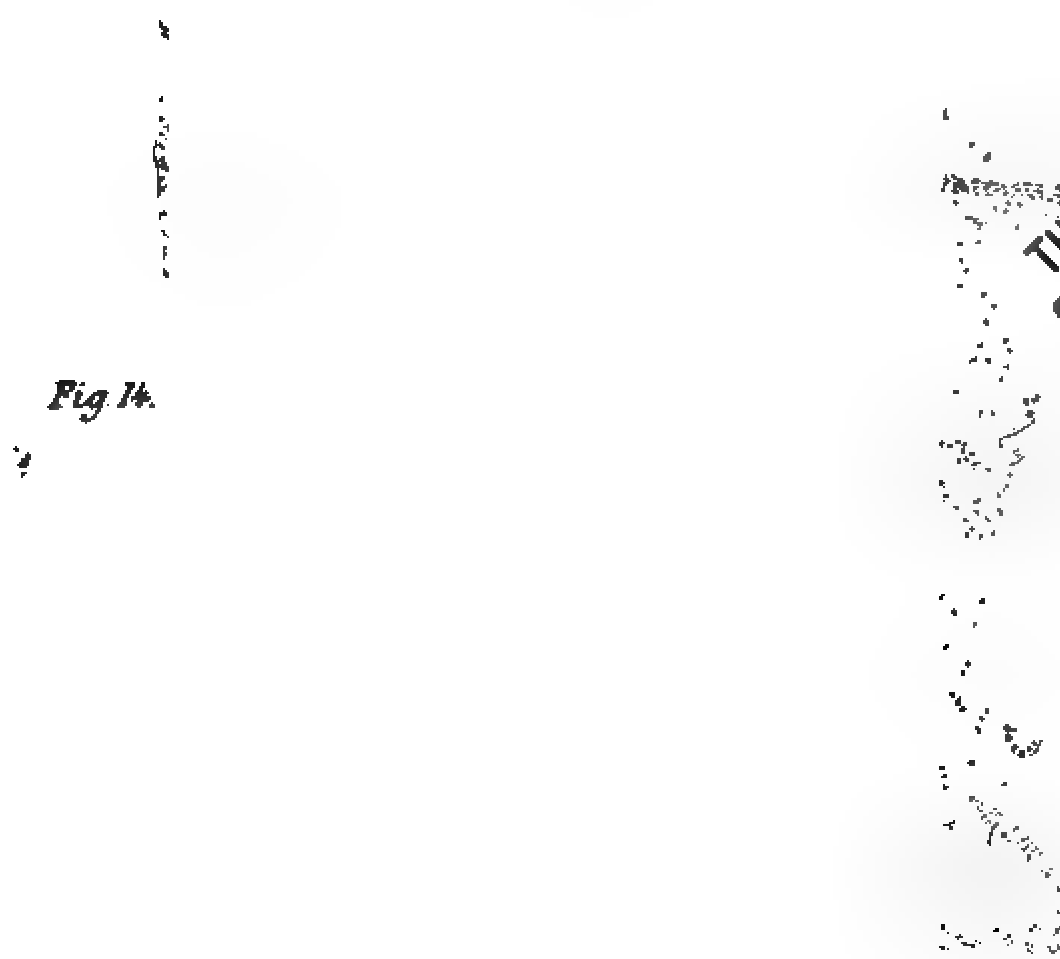
Fig 13.

Fig 14.



C Creighton, del. F Huth, Lith^r Edin^r

PLATE II

BOVINE TUBERCULOSIS IN MAN.

R. Shreen Del

Vincent Brooks Day & Son Lith

PLATE III

BOVINE TUBERCULOSIS IN MAN

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Farran Del

Fig. 12.

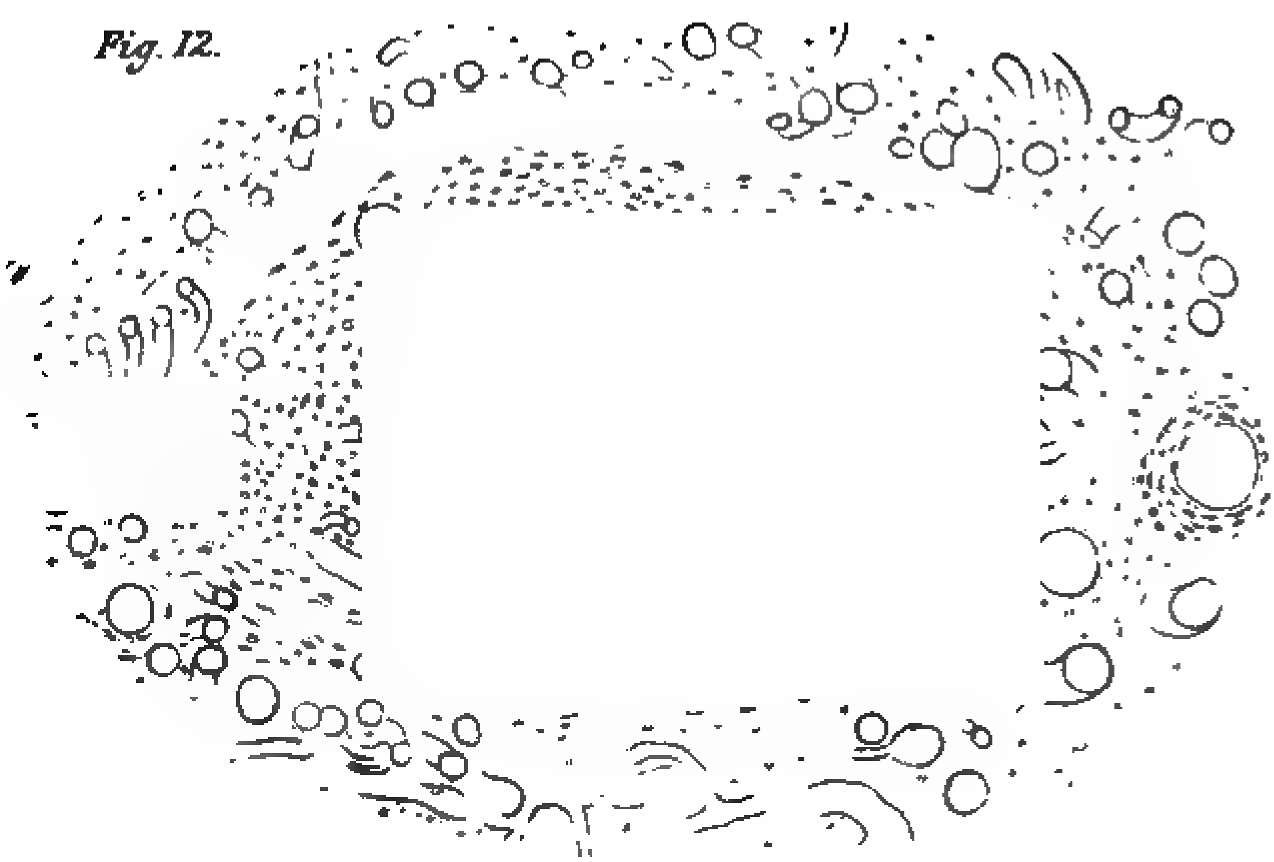

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Fig. 13.

Fig. 14.

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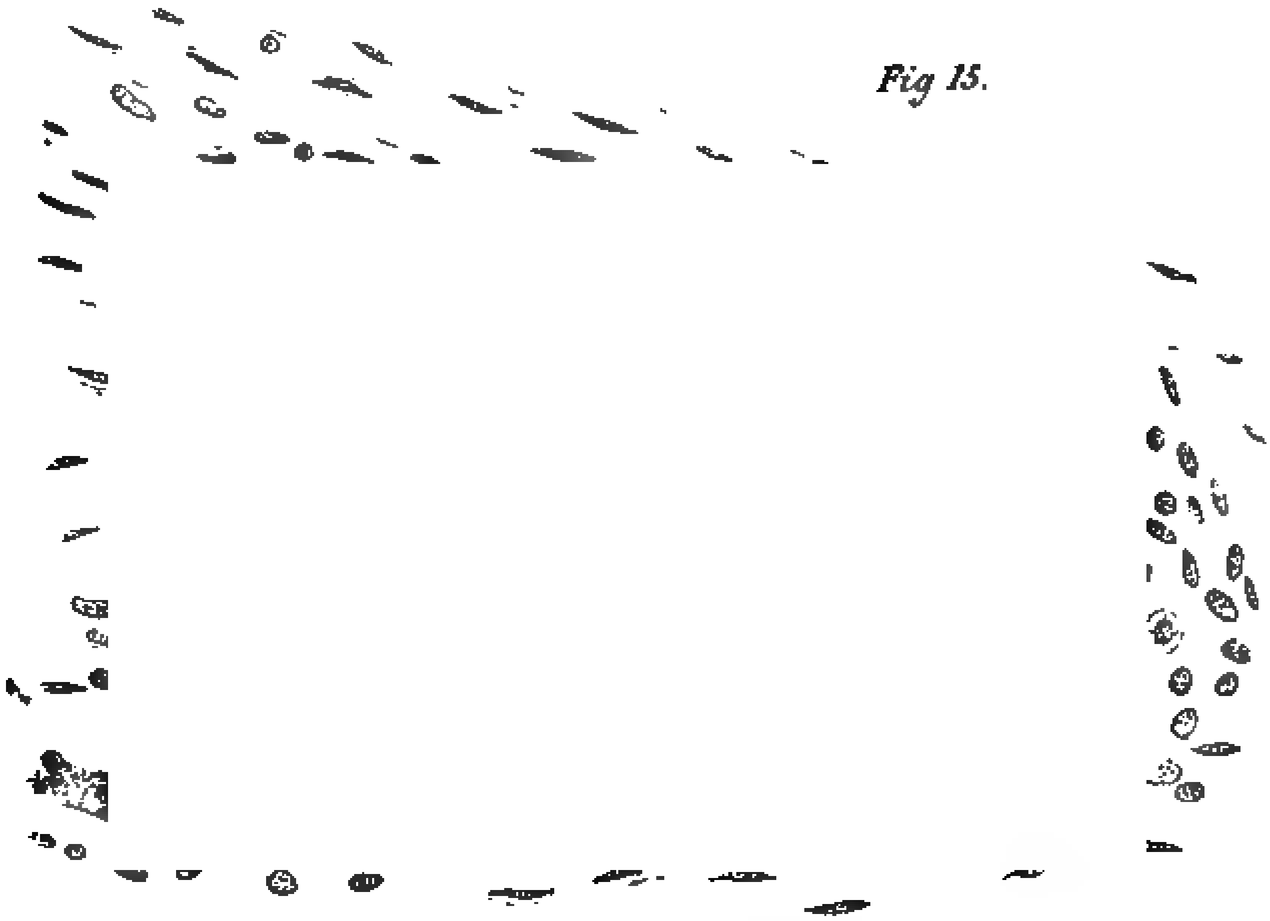

Fig 15.

Fig 16.

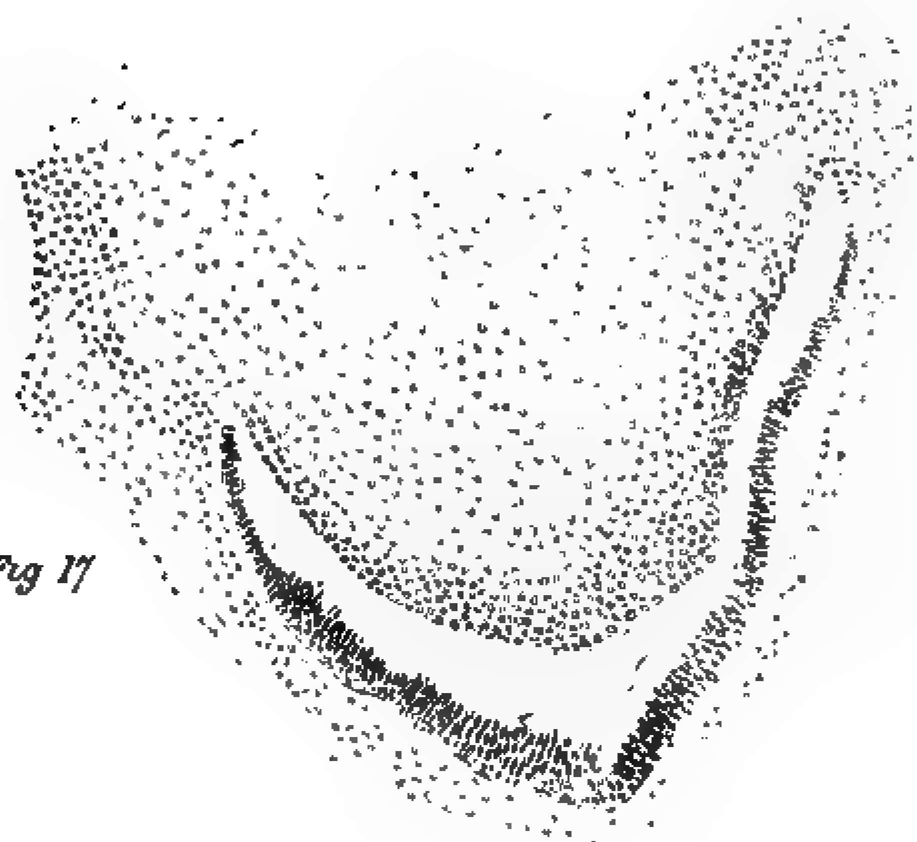

Fig 17.

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F. Huth, Lith[r] Edin[r]

Journ. of Anat. & Phys.
Vol. XV Plate VII Oct^r 1880

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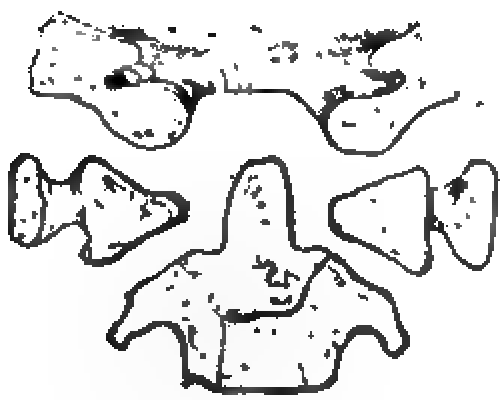

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Fig. 1.

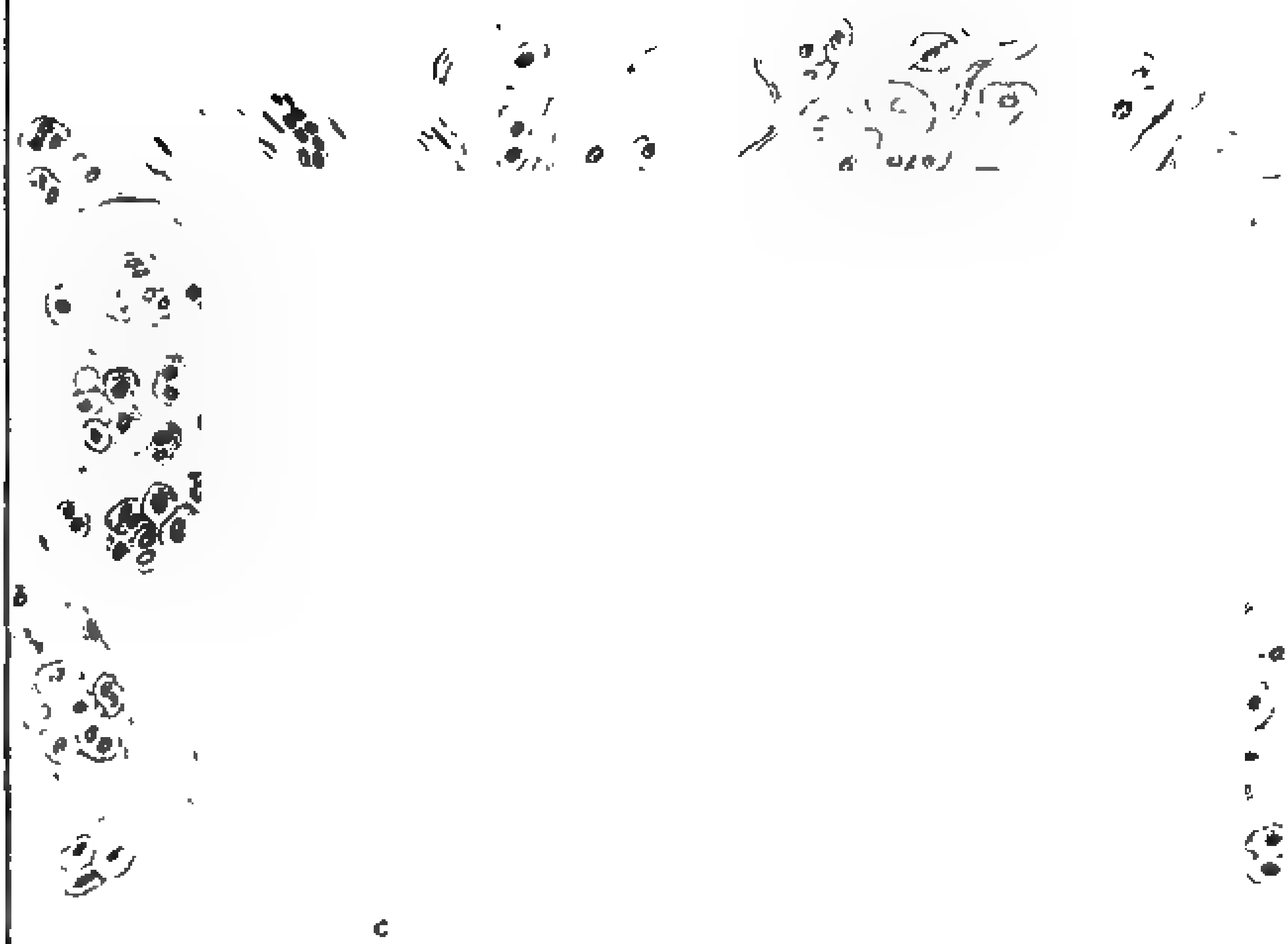
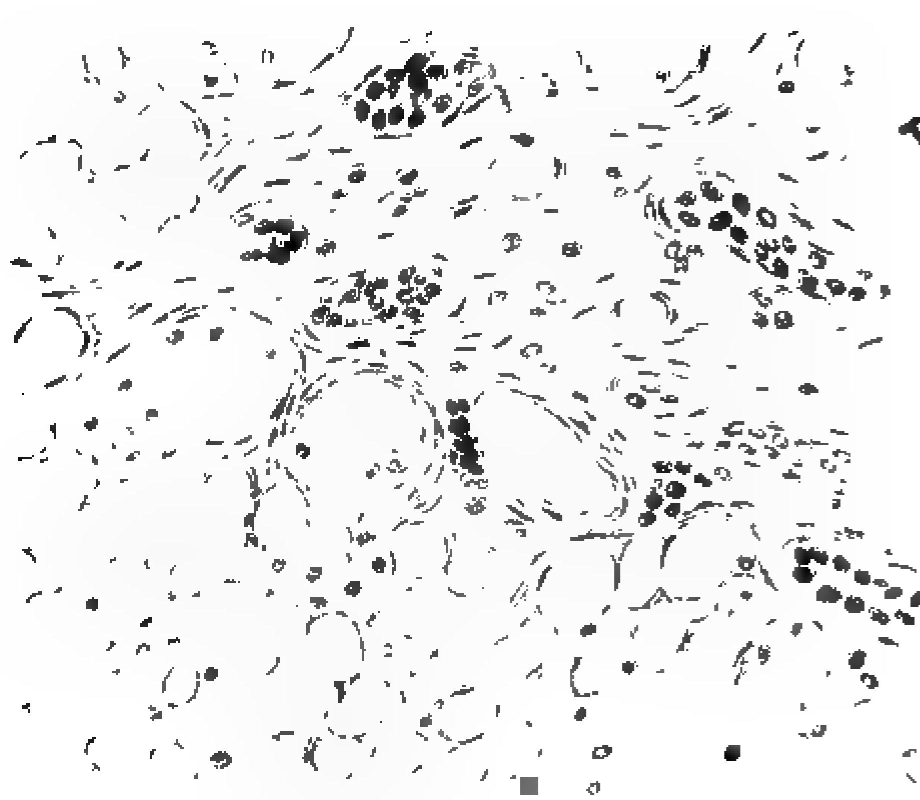


Fig. 2



A H Young, M B del

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Fig.

A H Young, M B. del

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Fig. 1

Fig 3

Fig 4

Fig 6

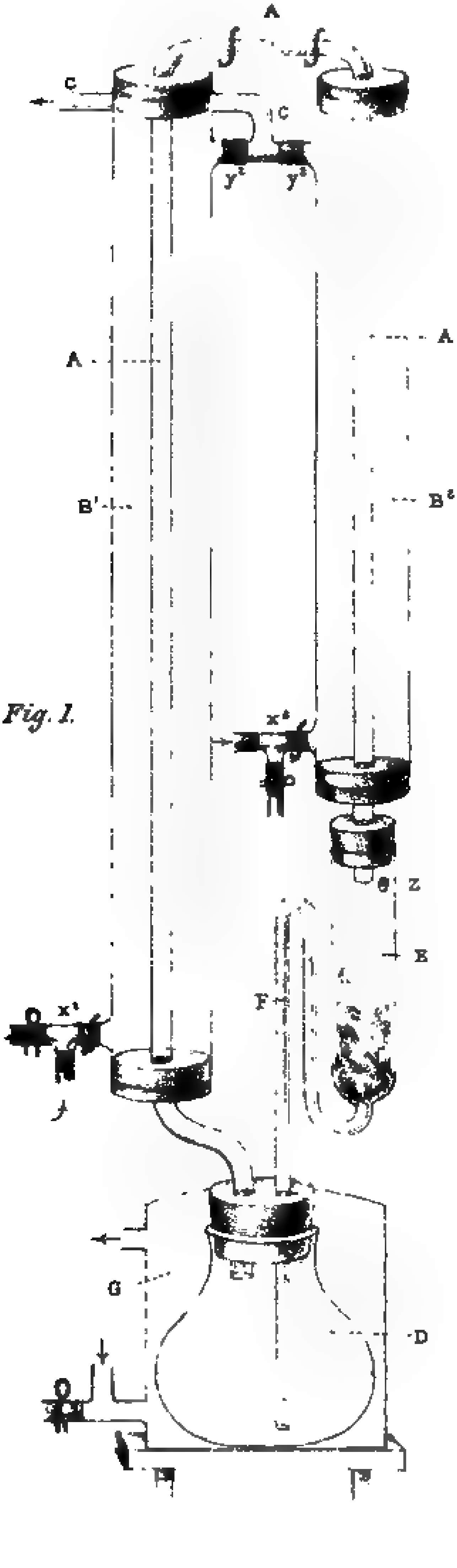

Fig. 1.

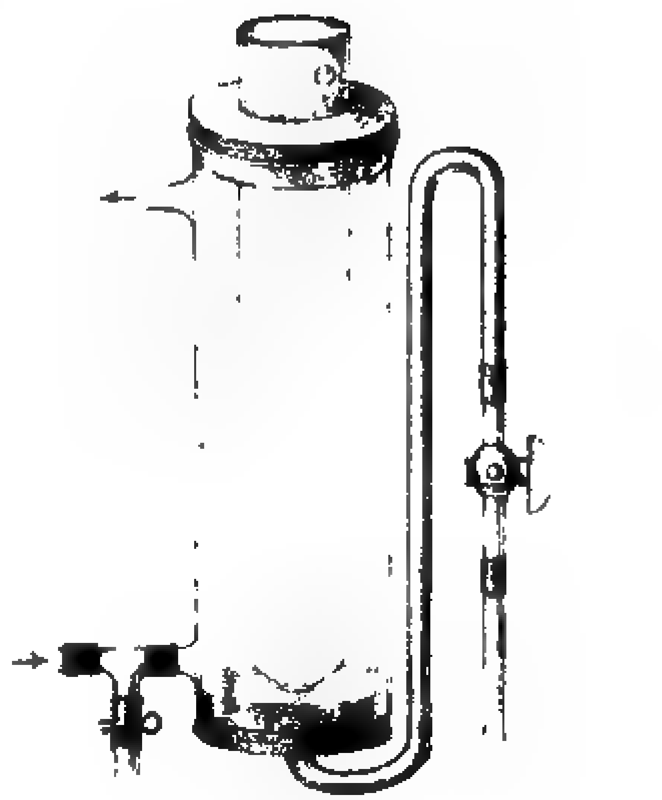

Fig. 2

F Huth, Lith. Edin.

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F Huth, Lith^r Edin^r

Journal of Anatomy and Physiology.

ON THE BONES, ARTICULATIONS, AND MUSCLES OF THE RUDIMENTARY HIND-LIMB OF THE GREENLAND RIGHT-WHALE (*Balaena mysticetus*). By JOHN STRUTHERS, M.D., *Professor of Anatomy in the University of Aberdeen.* (PLATES XIV., XV., XVI., XVII).

THE following inquiry was undertaken with the view of seeing what light the dissection of the soft parts might throw on the nature of the bony rudiments which were discovered many years ago by Professor Reinhardt of Copenhagen, attached to the pelvic bone in the Greenland Right-Whale, and which he interpreted as thigh-bone and leg.[1] All of these ten whales (*Balaena*

[1] This interesting discovery was made by Reinhardt in 1843, in a new-born female. Some doubt was entertained by Eschricht whether the one subsidiary bone he had found in *Megaptera*, and the parts previously found by his colleague Reinhardt in *Mysticetus*, were not rather "most analogous to the marsupial bones of the marsupial animals," but the opportunity of examining the parts in a half-grown female *Mysticetus*, taken in 1857, and in a full-grown male in 1860, satisfied these two observers jointly, that the two subsidiary bones are to be interpreted as originally suggested by Reinhardt (*Memoir on the Greenland Right-Whale*, by D. F. Eschricht and J. Reinhardt, 1861; translated from the Danish by Reinhardt, in Ray Society's Publications, London, 1866, edited by Professor Flower). This interpretation is adopted by Professor J. P. Van Beneden of Louvain, from the examination of a pelvis sent to that distinguished cetologist by Reinhardt, "qui a été préparé par les soins du professeur de Copenhague" ("De la composition du Bassin des Cétacés," *Bullet. Acad. Roy. de Belgique*, 2 série, tome xxv., 1868). The entire skeleton of that recently captured adult female *Mysticetus* was at the same time obtained for the Museum of the University of Louvain. So far as I am aware, these are the only specimens of the tibia of the Greenland Whale obtained and preserved in museums previous to those in my possession. The tibiæ are wanting in the skeleton of *Mysticetus* (captured in 1846) now in Brussels, obtained from the Copenhagen Museum; and also in the female skeleton in the Museum of the Royal College of Surgeons of London (1863), also obtained from the Copenhagen Museum. The tibiæ had no doubt been lost in preparing the skeletons.

mysticetus) were taken in Davis Straits. I was greatly indebted to Messrs Patrick H. Macleod, John F. Murison, Donald S. Macdonald, and George Grant, for the care with which, at no small personal risk, they carried out my instructions for procuring these specimens in Davis Straits. The parts were sent to me in Aberdeen, where I dissected them as time permitted between 1873 and 1876. As the dissections proceeded I made life-size drawings of the muscles, &c., and from these the drawings of the soft parts now given are reduced. The descriptions were written from the dissections before me. I gave an abstract of the results of these dissections, and exhibited the specimens, at the meeting of the British Association in Glasgow in September 1876. So far as I am aware, no account had previously been published of the ligaments and muscles connected with these rudiments. The number of specimens which I procured has enabled me also to make observations on the characters and variations of the bones themselves.

Although, from the size of the masses, their fragmentary nature, and the decomposing condition of some of them, the dissections were not easy, the inquiry was a most interesting one. Nothing can be imagined more useless to the animal than rudiments of hind legs entirely buried beneath the skin of a whale, so that one is inclined to suspect that these structures must admit of some other interpretation. Yet, approaching the inquiry with the most sceptical determination, one cannot help being convinced, as the dissection goes on, that these rudiments really are femur and tibia. The synovial capsule representing the knee-joint was too evident to be overlooked. An acetabular cartilage, synovial cavity, and head of femur, together represent the hip-joint. Attached to this femur is an apparatus of constant and strong ligaments, permitting and restraining movements in certain directions; and muscles are present, some passing to the femur from distant parts, some proceeding immediately from the pelvic bone to the femur, by which movements of the thigh-bone are performed; and these ligaments and muscles present abundant instances of exact and interesting adaptation. But the movements of the femur are extremely limited, and in two of these whales the hip-joint was firmly anchylosed, in one of them on one side, in the other on both sides, without trace of disease, showing that these movements may be dispensed with.

The function point of view fails to account for the presence of a femur in addition to processes from the pelvic bone. Altogether, these hind legs in this whale present for contemplation a most interesting instance of those significant parts in an animal—rudimentary structures.

The parts will be considered in the following order:—

In Table I. measurements are given of the pelvic bone from eleven Right-Whales, showing variations with sex, side, individual, and age.

In Table II. measurements are given of the femur and tibia from ten Right-Whales, showing variations.

Table I.—Measurements of the Pelvic Bone from

Whale.	Sex.	… of Whale.	… observed.	Length. … me		Length. Posterior part.		Length. Anterior part		Breadth. Greatest of posterior part.		Breadth. At angle.	
						R.	L.	R.	L.	R.	L.	R.	L.
I.	M	35	R. L.	8¾	8¾	8	8	3¾	3¾	1⅞	1⅞	2⅛	2⅛
II.	F.	58 to 60	R. L.	14½	15⅛	14½	14½	8½	8½	3½	3¾	5⅛	5⅛
III.	F.	48	R. L.	17	17⅛	15¼	15¾	7½	7½	2⅞	2¾	3⅝	4¼
IV.	F.	About 62	R. L.	15⅞	14¼	13⅜	13⅜	5½	6	2	2¼	3⅛	3⅞
V.	F.	44 to 45	R. L.	13½	13⅛	11¾	12	7½	7⅛	3⅛	4	4⅜	4⅞
VI.	F.	42	R. L.	10⅜	10⅞	9⅜	9¼	4⅞	4⅝	2¼	1⅝	3¾	3⅛
VII.	M.	48	L.	…	20	..	15¾		8⅝	…	2¼	.	2½
VIII.	M.	Good size, but not largest size.	R. L.	18⅝	19⅛	14½	14¾	8⅛	9	3½	3½	3	3⅞
IX.	M.	Large.	[illegible]	16½		16	.	5	…	3	…	3⅛	…
X.	F.	Not very large	R. L.	13½	13⅞	12⅞	11⅛	6½	6¼	2⅝	2⅞	4	3⅝
XI.	F.	Found on shore.	R.	18⅛	.	14	…	9⅛	…	3⅞	..	3⅛	..

Explanations of Table I.

1. The "lengths" are exclusive of the cartilages. The thickness of the cartilages which were present is given in the text (section 7).
2. The "posterior part" is measured to the anterior end of the promontory.
3. The "anterior part" is measured from the outer side of the promontory.
4. The "thickness at angle" is taken at the middle of the angular part of the bone.
5. By "angle" is meant the angle formed posteriorly by the meeting of the axis of the posterior part with the axis of the anterior part of the bone.

ELEVEN GREENLAND RIGHT-WHALES (*Balaena mysticetus*).

Thickness.				Depth of the Concavities.							Weight when cleaned and dried.		Figured in the Drawings.
											R.	L.	No.
3/8	3/8	7/8	...	...	...	...	...	.	120	120	...	..	11, 12, 13, 14, 15
1 5/8	1 5/8	3/4	1	3 3/8	[illegible]	3/8	1 1/4	1/8	90	100	15·368	17·20	1
1 1/4	1 1/16	3/4	3/8	2 5/16	3/8	1/2	1 5/16	11/16	130	130	14·160	14·140	16, 17, 18,
3/8	5/8	5/16	3/8	1 5/8	9/16	5/16	1/8	3/8	135	135	7·369	7·332	5
5/8	3/8	7/8	11/16	2 7/8	1 7/16	1/2	1/2	3/32	115	113	15·369*	10·424	3
5/8	5/8	5/8	5/8	1 1/2	5/8	5/16	1 1/16	3/16	125	125	6·399	5·254	..
...	1 3/4	..	3/4	2 1/8	5/8	1/8	1 1/8	1/8	...	143	..	21 389	8
2 1/4	2 3/4		...	2 1/8	1/8	1/2	1	5/8	145	145	40·90*	42·200*	10
1 1/8	...	1 7/8	...	1 3/8	1/8	1 5/8	3/8	3/8	135	...	29·369	...	7
7/8	11/16	5/8	9/16	2 5/16	9/16	11/16	5/16	5/16	125	130	8·239	8·85	..
7/8	...	5/8	...	2 7/8	1 1/2	1/8	1	3/4	135	...	13·344	...	...

6. The measurements are given in inches and parts of an inch (English).

7. The weights are given in ounces and grains (English). In each column the first figures are ounces, the second figures are grains.

8*. The weight of the pelvic bone in Whale No. V., of the right side, includes that of the anchylosed femur (weight of left femur, 2 ounces 430 grains). The weight of the pelvic bone in Whale No. VIII., of both sides, includes that of the anchylosed femur, for which fully 5 to 6 ounces may be allowed.

TABLE II.—MEASUREMENTS OF THE FEMUR AND TIBIA FROM

WHALE.	FEMUR.													
	Length of Femur.		Breadth.						Thickness.					
			Head.		At middle.		At distal end.		Head.		At middle.		At distal end.	
No.	R.	L.	R.	L.	R.	L.	R.	L.	R.	L.	R.	L.	R.	L.
I.	5⅜	5⅛	1	1	1⅛	1	1¾	1¾	½	½	$\frac{9}{16}$	⅝	1	1
II.	7¾	7⅝	1¼	1	2⅝	2⅜	2¾	2¾	$\frac{7}{16}$	½	1½	1⅝	1⅜	1½
III.	9	8½	1¾	1⅛	1⅛	1⅜	2½	2½	1	⅞	⅝	⅝	1½	1½
IV.	4	4¼	⅜	⅝	2⅛	$2\frac{5}{16}$	2⅜	2⅜	¼	⅜	1	⅞	$\frac{15}{16}$	1
V.	5	3⅝	...	¾	2⅝	2⅞	3⅝	3⅜	...	⅛	1⅜	1⅞	2	2
VI.	6¼	6	1¼	$1\frac{3}{16}$	1⅝	1⅝	2½	2½	½	½	$\frac{11}{16}$	¾	1⅛	1⅛
VII.	...	8¼	...	1¾	...	2½	...	3½	...	1	...	1	...	1⅜
VIII.	7	7	...	...	2¾	2¾	4⅛	4⅛	...	...	1¼	1¼	1⅞	1⅝
IX.	6¼	...	1⅛	...	2½	...	4	...	⅝	...	2	...	2¼	...
X.	5⅜	...	⅛	...	2½	...	2¼	...	¼	...	⅞	...	1⅜	...

EXPLANATIONS OF TABLE II.

1. For the sex, and the length, of each of these whales, see the same ten whales in Table I.

2. The length of the femur is exclusive of the cartilages. The thickness of the cartilages which were present is given in the text (section 11).

TEN GREENLAND RIGHT WHALES (*Balaena mysticetus*).

Femur.		Tibia.												Figured in the Drawings.
Weight when cleaned and dried.		Length of Tibia.		Breadth.				Thickness.				Weight. Moist in spirit.		
				At base.		Half-inch from apex.		At base.		Half-inch from apex.				
R.	L.	R.	L.	R.	L.	R.	L.	R.	L.	R.	L.	R.	L.	No.
...	...	2 3/8	2 4/8	1	7/8	6/8	5/8	5/8	4/8	3/8	3/8	...	...	11, 12 13, 14
5·10	4·284	3 3/8	3 7/8	1 1/2	1 1/2	7/8	7/8	1	1 1/8	4/8	4/8	1·180	2·4	1, 2
3·325	3·339	Injured		...	...	...	...	...	...	...	...	...	...	16, 17 18
1·315	2·6	3 1/8	...	1 1/4	...	6/8	...	1	...	5/8	...	1·4	...	5, 6
*	2·430	3 3/4	3 1/8	1 6/8	1 7/8	6/8	1	1 1/4	1 1/4	5/8	6/8	1·351	2·30	3, 4
3·30	2·130	Not obtained						...	...	..	...	...	...	...
...	5·383	...	4 1/4	...	1 6/8	...	7/8	...	1 1/4	...	4/8	...	2·13	8, 9
*	*	Injured		...	2 1/2	...	...	...	1 1/8	...	...	...	...	10
7·70	...	Not obtained						...	...	...	...	...	...	7
2·339	...	Not obtained						...	...	...	...	...	...	...

3. The breadth and thickness of the tibia "at base," were taken on a level with the posterior angle of the base, and therefore about 3/8 inch from the extreme anterior end.

4. As in Table I. the measurements are in inches, the weights in ounces and grains.

5. The weights of the femur in No. V. right, and in No. VIII., are included in those of the pelvic bones to which they are anchylosed. See Table I.

(A.) THE BONES.

I. The Pelvic Bone.

1. *Its Nature.*—The use of the terms ischial, iliac, and pubic, applied to the different processes of the pelvic bone, diverging from the acetabulum, would be convenient and would simplify the names of the muscles and ligaments, but, as there is no evidence that the pelvic bone is developed from more than one centre of ossification, these terms are apt to mislead. The term innominate for like reason is objectionable. The anterior part no doubt suggests the horizontal ramus of a pubes, especially in some, but if we look at the pelvis of a seal, in which the ilium and femur are greatly reduced, that part of the pubes is seen to be directed backwards like the ischium. If we suppose the anterior of the two slender bones of the dugong, which afterwards anchylose together, to be omitted, we have the Cetacean pelvic bone represented by the ischium alone, sending off two processes, anterior and posterior, at its acetabular part. These are for muscular and ligamentous attachment. The posterior part, besides attaching muscles and ligaments, attaches the crus penis, entitling us to regard the one pelvic bone as an ischium. The pelvic bone will therefore here be spoken of simply as presenting a posterior part, an anterior part, and an angular part, the latter projecting externally as a promontory. The posterior part may be conveniently termed the body, the anterior part the beak.

2. *Characters and Adaptations of the Pelvic Bone.*—Viewed as a whole the bone presents two surfaces, superior and inferior, and three borders, internal, external, and anterior, the two latter separated by the promontory. Longitudinally, each surface presents two curvatures; the under surface, very concave along its anterior half, and convex along its posterior half; the upper surface, the reverse. Each of the three borders is concave, the outer and inner borders becoming more or less convex behind, according to the shape of the posterior end.

(*a.*) *Posterior Part, or Body.*—The hinder end, rough, attaches the great interpelvic ligament, and, together with the inner margin near it, varies greatly with sex. On the superficial surface a prominent ridge is seen, directed forwards and inwards. It attaches the great posterior ligament of the femur. The outer

slope of the surface attaches, along its hinder half, the caudal muscular mass, the internal and broader slope, the perineal mass. The deep surface is occupied, along its hinder half, by the same muscles, but the dividing ridge is less marked on this surface. These ridges or elevations, more or less marked, may be traced forwards to the inner border of the bone, at or in front of the angle, and mark off the outer attachment of the great genital muscular mass.

(*b.*) *Angular Part.*—The characters here are the result of adaptations to a hip-joint; an outward extension of the bone supports a hollow for the reception of the femur, and is surmounted by a prominence to which ligaments and muscles are attached. Seen on surface, the promontory is more or less rounded, usually presenting two projections, one external supporting the acetabulum, the other, anterior, for muscular attachment, is more variable. Seen on the edge, the anterior part of the promontory is broad and rough, the outer part thin, being excavated by the acetabulum. If the cartilage is off, the part which it covered may be recognised as an excavated and usually rough area, of an ovoid form. The general acetabular hollow may be very shallow or it may be well cupped.

(*c.*) *The Anterior Part or Beak* tapers gradually from the broad part at the angle to the point. The breadth of this part varies much with that of the angle. About the middle, the breadth is usually about three times as great as the thickness. As at the angular part of the bone, the inferior surface is concave both ways, forming a continuous hollow for the reception of the femur. The more or less transverse position of this part of the pelvic bone adapts it for the attachment of strong muscles which pass backwards to it from the trunk. It also supports the thigh-bone, and attaches ligaments and muscles by which that bone is retained and moved.

2. *Differences of the Pelvic Bone in the Male and Female.*—These differences are more marked than in the human subject. In the female the pelvic bone is shorter, more bent, broader at the angle, and, above all, thinner at and towards the hinder end, than in the male. The shortness is partly owing to the greater bend. Thus in No. II., while the length is 14½ inches, the united lengths of the two portions is 23 inches, the angle being 90°;

while in No. VIII., the length being $18\frac{5}{8}$ inches, the united lengths is $22\frac{5}{8}$ inches, the angle being 145°. But, irrespective of angle, the measurements given in the table show that the bone is shorter in the female. In the 62 feet long female (No. IV.), with an angle of 135°, the length is about 15 inches, while in the 48 feet long male (No VII.) with an angle of 143°, the length is almost 20 inches, the united lengths of the two portions in each being, respectively, 19 and 24 inches. The greater bend of the bone in the female than in the male is probably related to the differences in the external organs or passages. The reason for the exceeding breadth of the bone at the angle in the female is not evident, unless it be the greater thickness in the male, and that the genital muscular mass goes farther forwards on the bone in the female. But the chief difference in the sexes is on the posterior part of the bone, which is so thick and narrow in the male as to be almost rounded in appearance, while in the female it is thin, and may be also broad. The adaptation here is seen by referring to the attachment of the interpelvic ligament to the bone. In the male the thick rounded ligament, supporting the crus penis, is attached to the hinder end of the bone, while in the female the more expanded ligament reaches forwards along the inner margin and upon the bone. It is on the inner side that the increased breadth is gained in the female. In the young female (42 feet long) the expansion towards the hinder end is little marked, nor is it much marked in No. X., while in No. XI., a very fully ossified specimen, the breadth near the hinder end is even greater than at the angle. This thinness of the hinder end is seen in all the female specimens before me, in marked contrast with the thick abrupt ending of the bone in the male.

By referring to the column of weights in Table I., it will be seen that the pelvic bone is much heavier in all the adult males than in any of the females. While among the adult females it varies from about 17 ounces to less than half that weight, in the three adult males it varies from 21 ounces up to 29, and in No. VIII. is probably about 35 ounces.

4. *Individual Variations of the Pelvic Bone.*—While presenting the above characters by which these bones may be recognised and their sex distinguished, they yet present considerable individual variations. Reference may here be made to

the measurements given in Table I. Among the females, the *bend* varies from an angle of 135° to 90°. In the two adult males, Nos. VII. and VIII., the angle is large (143° and 145°), but in the young male (35 feet long) it is only 120°. These specimens give us no ground to suppose that the angle changes with growth or age, although the ends grow at the cartilages. Nos. II. and V. (figs. 1 and 3) have the appearance of being fully adult or old, and they are very much bent (angles 90° and 115°); Nos. IV. (fig. 5) and XI., equally adult or old, have angles of 135°; while No. VI., imperfectly ossified, and No. III. (fig. 16) more fully ossified, have angles, respectively, of 125° and 130°.

The variation in *robustness* is great (as the column of weights indicates), putting aside Nos. I. and VI. as immature. No. VIII. is much more robust than No. VII., especially at the hinder end, where it enlarges onwards to an abrupt rough end, over 3 inches by 2½ inches, facing backwards and inwards, when the interpelvic ligament is attached; while No. VII., though quite as thick at about 4 inches from the end, diminishes conically to a blunt end, not a third the size of the end of No. VIII. The third adult male, No. IX., is here intermediate in form between these two; broader than No. VIII., but not so thick, and terminating in a thick and rough but not expanded end. Among the seven female specimens the differences are still greater. Those of No. IV., the longest of these whales, are very slender, more so than in the 42 feet long individual. There is great variation also in the extent, form, and position of the expansion towards the hinder end. This expansion is much less marked in Nos. III., VI., and X. than in Nos. II., V., and XI.; in No. II. it is greatest at 4 inches from the end, giving an oval, or pointed, end; in No. V. it is greatest behind, giving a somewhat square-shaped end, most pointed externally; in No. XI. the form is intermediate between the two last.

There are likewise well-marked variations in the degree of the *curvatures*. The curvature of the inner border is increased when the bone is broad behind, or when, as in No. X., the hinder part of the body is curved inwards. There is variation in the abruptness with which the promontory stands out, influencing the curvatures of the outer and anterior borders, but variation in the

abruptness of the promontory is seen more where it joins the anterior part than where it supports the acetabulum. Nos. III. and IV. (figs. 16 and 5) illustrate this well; on the other hand No. XI. shows the greatest projection at the acetabulum, which in it is large and deep. The curvatures of the surface are, in the adult males, variously marked; least in No. VIII., in which the concavities are mainly owing to the enlargement at the hinder end. Among the females they are strongly marked in Nos. III. and IV., well marked in No. VI., and very slight on the body in Nos. II. and V., in which the expansion posteriorly is great. But in all these specimens, male and female, there is the well-marked concavity of the under surface at and in front of the angle, corresponding to the position of the thigh-bone.

The shortness of the beak in No. VI. is due to immaturity, and in No. X. also the ossification of this end is incomplete; but in No. IX., in which the ossification is complete, the beak presents a remarkable variation (fig. 7). Although the measurement in the table, taken from the outer side of the promontory, gives 5 inches, the length of the projection, from where it leaves the inner side of the bone, is only 3 inches (on the anterior border only 2½), and, instead of being flattened like the others, it is a prism, the anterior and posterior surfaces broader than the surface next the femur. Variations of the acetabulum will be noticed with the hip-joint.

5. *Symmetry of the Pelvic Bones.*—Considering that, although arranged so as to present the appearance of a pelvic girdle, the girdle is without a symphysis and has no function of resistance to perform, the symmetry of these bones is remarkable enough. The a-symmetries noted in the table are slight; mainly little differences in the extent to which ossification has extended at either end. Nos. II., VI. and VIII., however, show considerable difference in weight between the right and left pelvic bone.

6. *Foramen.*—A small foramen is present in most of these specimens, near the inner border, in front of the angle. It is oval, scarcely as large as a crow-quill, and directed, generally, from the under to the upper surface, outwards and backwards. It is absent in both pelvic bones of Nos. II. and VI.; in No. VII., and in the right pelvic bone of Nos. IV. and V., and in

the left of No. X., although well-marked on the other bone in these three. In Nos. V. and IX. its direction is different; from the under to the upper surface, its direction in No. IX. is forwards and inwards, in No. V. forwards and outwards.[1]

7. *The Cartilages of the Pelvic Bone.*—In No. I., the young male, the cartilage of the hinder end is 1 inch in length, continuing the full thickness of the bone backwards and a little inwards, and then attaching the interpelvic ligament. The cartilage of the anterior end is 2 inches in length, tapering to a blunt point, to which a fibrous tuft is attached. In No. V., the anterior cartilage is about $\frac{1}{2}$ inch long, to which a fibrous tuft still remains attached. At the hinder end, which is broad and thin, the cartilage is 1 inch in length externally, $\frac{1}{2}$ inch internally, with a narrow strip along the end between the two corners. When the cartilages are off, the hinder end of the bone presents corresponding appearances; the bevelled corners $\frac{1}{4}$ inch thick with irregular surface, the intervening edge about $\frac{1}{8}$ inch thick and more finished looking. From these appearances of the bone, as well as from the length of this whale (44 to 45 feet), it may be inferred that it was not quite adult, although the right femur is anchylosed to the pelvis. In No. VI., the young female, both the cartilages are lost, exposing the irregular surfaces which have supported them. A cartilage was present on the anterior end of No. III. (about $\frac{1}{4}$ inch long), of No. IV. ($\frac{1}{2}$ inch), of No. VII. ($\frac{1}{6}$ inch) and of No. VIII (a thin layer); intervening between the fibrous tuft and the bone. Ossification having gone farthest on the inner, or posterior, border, the anterior end is very oblique in all the specimens,

[1] *Comparison with the Pelvic Bone in the Great Fin-Whale.*—Comparing these adult male specimens with that of the adult male Fin-Whale (*Balænoptera musculus*) which I figured in 1871 (*Journal of Anatomy and Physiology*) the differences are striking. In that Great Finner the posterior division is shorter by 3 inches (9 and 12) than the anterior, and attaches the crus penis along its posterior $\frac{2}{3}$; and the anterior half of the anterior division is flattened in the opposite direction. In *Mysticetus*, the posterior division averages about twice the length of the anterior. In the Finner the bone is less bent, and the promontory stands out farther and more abruptly, giving a breadth of 5 inches to the bone at this part. There is no acetabulum, or impression of the pelvic bone by the short ovoid rudimentary femur, which lay loosely in the hollow of the border of the bone, $1\frac{1}{2}$ inch in front of the promontory, to the hinder part of the under surface of which was attached the strong triangular ligament, 2 to 3 inches in length, which tied the femur to the pelvis.

except in Nos. IV. and V., in which the obliquity is moderate, in No. II. in which it is slight, and in No. IX. in which the stunted beak tapers to a blunt point. In No. XI., a more contracted and rough portion, ¾ inch in length, and about half the thickness of the bone from which it projects, has been concealed by the cartilage.

Any cartilage which may have existed at the *hinder* end of the other specimens (Nos. II., III., IV., VI., VII., VIII., IX., and X.) had been detached with the remains of the ligament. The thin flattened ending in Nos. III., IV., and VI., present the irregular surface of parts which have supported cartilage. No. II. comes to a sharp edge with a finished look, while at the anterior end the surface has evidently supported a cartilage. No. XI. has the same finished look behind. The abrupt ends in the three adult males are coarsely irregular.

It would seem from these facts that the cartilage of the posterior end is shorter in the young than that of the anterior end, and still more so in the adult, but these observations do not determine whether cartilage remains permanently at the hinder end. The cartilage of the acetabulum will be examined with the hip-joint.

The *Periosteum* of the pelvic bone is about $\frac{1}{12}$ inch thick on the surfaces. On the margins, along the three concavities, there is a fibrous wall, ½ inch deep, prismatic in section, filling up the deepest part of the concavities and giving increased breadth.

II. The First Appendicular Bone (The Femur.)

8. *General Characters.* — Among these ten Greenland whales the thigh-bone presents great variation in form, but certain general characters may be recognised. All are sufficiently flattened to present, along the whole bone, two surfaces, separated by an anterior and a posterior border. There is evidently a head, followed by a more or less elongated neck. The neck is defined distally by two tubercles, one on each border, the posterior nearer the head than the anterior; and, beyond this, there is a more or less square-shaped and onwardly enlarging body, the end of which presents a flattened ovoid articular surface, from which, as from the head, a cartilage has been detached in the macerated bone. The right femur may be

distinguished from the left by observing that the deep surface is longitudinally convex, and that the axis of the bone is bent with the concavity backwards.

The *Head* is much flattened in all, an ovoid at the best, and in some reduced to a mere rounded border. It is generally placed obliquely to the axis of the bone, extending farther upon the anterior than on the posterior border of the neck. It presents an irregular surface where the cartilage lay. The *Neck*, a little more contracted than the head, expands gradually onwards to the tubercles. The *posterior tubercle* attaches the great posterior ligament of the femur. It may be regarded as the *great trochanter*. If the ordinary mammalian femur, much shortened, be flexed, adducted, and rotated outwards, it will be brought into the position of the femur in *Mysticetus*. More exactly, if the pelvis and femur of a seal be taken in the hands and so manipulated, the correspondence becomes evident, and it is seen that this tubercle is the trochanter major. It is situated generally at about the junction of the proximal and middle thirds of the bone, but may be somewhat to either side of that point. It occurs as a triangular elevation of the posterior border, varying in abruptness and degree of elevation. The *anterior tubercle* is situated on the anterior border about the middle of the bone, and is rather the angle where the sloping neck joins the more horizontal body than a special process.

The *Body* includes from half to two-thirds of the length of the bone, is the thickest as well as the broadest part, and increases distally, especially in breadth, so as to give a somewhat triangular instead of a quadrangular appearance to the bone. The *distal end* is seen, when the cartilage is removed, to be ovoid, or elongated in the more flattened specimens; a little convex longitudinally, with its most projecting part in front of the middle; to face obliquely downwards, from the ossification having extended further on the deep surface, it may be for fully ½ an inch, than on the superficial surface; and to present the usual irregular appearance of parts which have supported cartilage.

Viewing the surfaces and borders of the femur as a whole, the *deep surface* is longitudinally convex, except near the head, this convexity of the femur corresponding to the concavity of the

pelvic bone at and in front of the angle. The *superficial surface* is, longitudinally, concave along the outer half, convex along the body, this convexity being gained by the increased thickness of the bone. The borders are thin along the neck, thick along body.

9. *Individual Variations of the Femur.*—Reference to the table (Table II.) will show that the adult femur varies in length from (without its cartilages) under 4 inches to 9 inches; in breadth, at the distal end, from 2½ to 4 inches; and in thickness, at the same part, from 1 inch to 2¼ inches. Among these specimens the following variations of general form may be distinguished: (1) elongated and body square-shaped (Nos. I., II., and VII); (2) elongated and gradually enlarging (Nos. III. and VI.); (3) elongated and body triangular and thick (Nos. VIII. and IX.); (4) short and body thick (No. V.); (5) short and body flattened (Nos. IV. and X). The somewhat square-shaped body, but broader distally than towards the neck, may be regarded as the typical form of body. The neck shows considerable variety in regard to constriction, length, and bend; and the head no less so in regard to size.

Some of the variations presented by the specimens may be here noted. Nos. I. and II. (figs. 11, 12, 1 and 2) have the characters well marked, and resemble each other closely, but the body of No. I., that from the young male, is thin. In No. II. the body is unusually thick at the middle, gained by convexity of the superficial surface. No. VII. (figs. 8 and 9) presents a posterior tubercle projecting suddenly for ¾ inch on the cervical side, but with scarcely any projection on the distal side, giving the body a very abrupt commencement on the hinder edge. The want of an anterior tubercle tends to give the whole bone, in No. VII., a somewhat triangular appearance, but the body has the square form, broadening distally. The ovoid head is very oblique, with a pointed posterior end. No. III. (fig. 16) has a large and well-formed ovoid head. There is no distinction between neck and body, both tubercles being absent. The absence of the posterior tubercle was explained by the condition of the great posterior ligament, which was exceptionally broad and thin. This is the longest of these specimens. No. VI. resembles the last, but with a transition to the square form of

body. The trochanter is represented only by a distinct roughness at the part. No. IV. (figs. 5 and 6) is the smallest of all these specimens, but has the characters well marked. The head is an ovoid, scarcely half an inch in length. The neck, well marked off at both ends, is very much bent, the convexity towards the pelvic bone. This bend is most marked on the left femur, in which the neck, which is also longer than that of the right, meets the body at nearly a right angle. The bend is opposite the trochanter, 1½ inch from the head. The concavity thus formed on the under surface is 1 inch in depth. The body is very square-shaped. No. X. has a close resemblance in form to No. IV., except that the neck is much less bent, and it is altogether a larger bone by from a fourth to a third.

No. V. (figs. 3 and 4) is the most anomalous of these specimens. The right has a short (3 inches long) square-shaped and very thick body; a neck as broad and thick as a thumb; and a good-sized head thoroughly anchylosed to the pelvic bone at the acetabulum. The left is free. Though at first view very irregular looking, this femur is simply a body, like the body of the right, but without a developed head or neck, these being represented only by a thin lamina, ¾ inch broad at the free end, projecting for ¼ inch outward from the body at the part where the neck should be. The *synostosis* of the right side is evidently of long standing, though this whale was probably not quite adult (44 to 45 feet long, and pelvic bone not quite finished behind), nor do the bones show any traces of disease. The form of the head is seen anteriorly and externally, the latter part projecting a little beyond the outer edge of the back part of the promontory of the pelvic bone; while, posteriorly, only a furrow marks where the anchylosis has taken place. Here the hinder edge of the acetabulum rises about ⅓ inch from the level of the surface of the pelvic bone before it reaches the place of anchylosis. The anchylosis involves also part of the neck posteriorly, but anteriorly the neck is free, and deeply between it and the pelvic bone there is a fissure into which the scalpel passes. On this side, therefore, a good sized head has been anchylosed in its socket, while, on the left side, the head and neck would seem to have become atrophied. The rudimentary head of the left side, however, naturally occupied the same position in relation to the pelvic bone as the anchylosed head of the right side does.

In No. VIII. (fig. 10) the body, marked off externally by a very distinct anterior tubercle and a slight posterior tubercle, expands so much distally as to have a decidedly triangular figure. The smallness of the trochanter accords with the anchylosed condition of the hip-joint. The *synostosis* must be of old standing, being very complete, and it is nearly symmetrical. I have met with an ostitic condition of the bones several times in this and in other species of the Cetacea, but here there are no traces of disease, and the form of the synostosis in this specimen, as well as the fact itself, is interesting. The place of anchylosis is not in a hollow, but on a platform projected from the pelvic bone. This platform is 3½ inches in length at the base, and has an elevation behind of ¾ inch, in front of ¼ inch. The base lies obliquely across the angular part of the pelvic bone, a little external to the middle, the hinder half of the base being opposite the promontory and reaching back to a little way internal to the usual position of the acetabulum, and there smoothly subsides. The place of union is marked by a shallow furrow, ⅛ inch or less in breadth, passing obliquely round. In length the place of union is 2 inches on both sides, in breadth 1 inch on the right, 1½ on the left side. The head and neck have somewhat broadened where they are soldered to the slightly concave top of the platform, but there is very little projection from the plane of the deep surface of the femur to meet the projection from the pelvic bone, on the left side none at all. On the left side the head is more sunk, though elevated enough to show its rounded outline; on the right side, the back part of the head projects obliquely for ½ to ¾ inch, like a rough finger-end, and is opposite the fore part of the recurved edge of the promontory. The platform above described may have followed or may have preceded the anchylosis, but if the heads in this case ever lay in the usual place of an acetabulum, they have been pushed forwards and inwards for fully 1½ inch by the growth of the platform. The direction in which the femur is anchylosed to the pelvic bone is not quite the same on the two sides, the left being more horizontal, so that its distal end is 1 inch behind that of its fellow; and more downwards, so that the interval between the end of the pelvic bone and the femur is ¾ inch on the right side and 1½ inch at the corresponding part on the left side.

No. IX. (fig. 7) is the thickest, and presents several strongly-marked characters. The head and neck are slender for so massive a specimen. The tubercle on the anterior border is strongly and abruptly developed, presenting a rough ovoid elevation 1¾ inch in length by ¾ inch in breadth. The trochanter begins abruptly on the cervical side, as in No. 7. The body is very thick, and somewhat prismatic, the third border, running as a sharp projecting edge along the deep aspect, from the trochanter to the distal end, nearly parallel to the anterior border and 1½ inch from it. The end of the bone from which the distal cartilage has been detached, is oval, 4 inches by 2¼, the corners of the broader and partially flattened anterior end of the oval, being the parts to which the anterior border and the sharp ridge above noted run. The surface of the end presents a rough undulating hollow, caused mainly by the greater projection of the upper margin. This femur is much the heaviest of all these specimens, but had the anchylosis not prevented that of No. VIII. being weighed separately, it would probably have proved to be quite as heavy.

10. The column of weights, in Table II., also shows the variation among these thigh-bones. Among the adult specimens, those from the males are heavier than any among the females, but the difference between No. II., female, and No. VII., male, is not great. Nos. II. and III., female, are the longest of the whole series, and No. VI., female, would have been a large femur in the mature state. As this bone does not attach any of the muscles of the reproductive organs, we would expect that it should not present any fixed sexual characters, but that it would vary with the general muscularity. The weight of the femur is seen to vary from between about a third to about a fourth of that of the pelvic bone, but without a constant proportion; and in No. II. the heavier femur goes with the lighter pelvic bone. In No. VI, the least mature of the specimens weighed, the femur is not much under half the weight of the pelvic bone. The more advanced ossification of the femur accords with the observation of Reinhardt in the new-born *Mysticetus*, that ossification had begun in the femur, at its middle, while the pelvic bone was as yet entirely cartilaginous.

The *symmetry* of the femur, in these seven pairs, is notable, notwithstanding their great variation in form and size in different individuals. Except in No. V., in which the right is

anchylosed, and in No. IV., in which the neck of the left is more bent, the differences between the right and left are but slight.

11. *The Cartilages of the Femur.*—The cartilage of the *head* varied in thickness in the different specimens, from $\frac{1}{10}$ or $\frac{1}{8}$ to $\frac{1}{4}$ or even $\frac{3}{8}$ inch. That of the distal end varied from $\frac{1}{10}$ to fully $\frac{1}{2}$ inch, generally thickest on the anterior half although the cartilaginous prominence (tibial condyle) supporting the tibia is on the posterior half. The distal cartilage in Nos. II. and VII. was only $\frac{1}{8}$ inch thick. In No. IV., $\frac{1}{8}$ to $\frac{1}{6}$. In No. III., at the tibial condyle $\frac{3}{8}$, anteriorly only $\frac{2}{8}$. In No. V., at the tibial condyle $\frac{3}{8}$, anteriorly $\frac{5}{8}$. In No. VIII., at the tibial condyle $\frac{1}{6}$ to $\frac{1}{4}$, anteriorly fully $\frac{1}{2}$ inch. In No. I., the young male, at the tibial condyle $\frac{1}{2}$, anteriorly $\frac{3}{4}$ inch. In this specimen the cartilage of the head was $\frac{1}{4}$ inch thick in front, $\frac{1}{8}$ behind. The thickness of the cartilages must not be judged of by the surface appearances, as they overlap the bone at the edges, concealing it may be as much as $\frac{1}{2}$ an inch of it. Sections must be made to see the true thickness at various parts.

The *periosteum* of the body of the femur is about $\frac{1}{8}$ inch in thickness.

III. THE SECOND APPENDICULAR BONE (The Tibia).

12. *Cartilaginous Condition.—Form.*—This element of the rudimentary limb is in all these specimens entirely cartilaginous. It is of a triangular or pyriform shape, articulating by an oval synovial surface on its base, with the cartilaginous condyle on the end of the femur, and tapering to a blunt apex about the size of the end of the little finger, from which a fibrous band is prolonged. The body is somewhat flattened, the surfaces superficial and deep, the borders inner and outer. The extreme length, from the anterior angle, or tuberosity, to the apex is, in the adult specimens from $3\frac{1}{8}$ to $4\frac{1}{4}$ inches; from the external angle, $\frac{3}{4}$ inch to 1 inch less. The greatest breadth, which is on a level with the external angle, is from $1\frac{1}{4}$ to $2\frac{1}{2}$, and the thickness at the same part is from 1 to $1\frac{1}{4}$ inch.

The *base* presents a shallow oval articular surface reminding one of the glenoid cavity of the human scapula. This surface measures 1 to $1\frac{1}{4}$ inch longitudinally, $\frac{3}{4}$ inch to 1 inch across. Beyond its raised margin is a narrow furrow, surrounded by the

attachment of the capsular ligament of the joint. The end of the base slants obliquely upwards, so that the articular surface is seen on viewing the tibia from its deep, not from its superficial aspect. By this character the right tibia may easily be distinguished from the left. The anterior angle projects somewhat beyond the articular surface, forming a rounded projection (anterior tuberosity of the tibia) to which part of the tendon of the anterior muscular mass is attached.

The form of the *body* is somewhat variable. In No. VII., the longest of the specimens, the deep surface is convex both ways, the superficial surface flat, or a little concave transversely; the outer border concave behind the base and thinnest, the inner border undulating, with two concavities. In No. II., the outer border is mostly convex, the inner mostly concave; both surfaces are about equally convex transversely, and the left tibia is $\frac{1}{2}$ an inch longer than the right. In No. V., the base is so large that both borders are concave, the right tibia (the side on which the femur is anchylosed to the pelvis) is $\frac{5}{8}$ inch longer than the left, and is narrower than the left, so as to be almost round; both are more convex transversely on the superficial than on the deep surface, and both are bent longitudinally, the concavity on the deep aspect. No. IV. is nearly straight, the undulations on the borders slight, and is so equal as almost to appear a round elongated cone, cut obliquely at the base.

Variations in the flexibility of these tibiæ are mainly due to the differences in form. Allowing for this, those of the adult males are perhaps the least flexible, but the left tibia of No. II. is as dense as they are, while the right is softer and more flexible. In the young male (No. I.), the cartilage is so soft that it may be bent so as nearly to make the ends touch.

The above measurements include the *perichondrium*. This fibrous capsule is about $\frac{1}{6}$ inch thick on the surfaces, thicker at the borders. It is not very easy to fix the limit between the perichondrium and the fibrous structures attached to it, but what may be regarded as the perichondrium proper is from $\frac{1}{4}$ to $\frac{1}{2}$ inch thick along the borders, thickest at the outer border. The cartilage proper is, therefore, not so large as in the measurements given, except in length. From the breadth fully $\frac{1}{2}$ an inch, and from the thickness $\frac{1}{3}$ inch may be deducted. In sections the cartilage is seen to be traversed by an abundance of vascular canals.

(B.) THE LIGAMENTS, ARTICULATIONS, AND MOVEMENTS OF THE FEMUR AND TIBIA.

I. THE KNEE-JOINT.

13. A well-marked synovial cavity was found between the femur and the tibia in all these dissections. The adaptation of the end of the tibia so as to form an oval glenoid articular cavity has been described above. On the femur the distal cartilage presents a corresponding oval elevation, which may be termed the *condyle;* 1 to 1¼ inches in length, antero-posteriorly, ¾ to 1 inch across; convex in both directions but more especially across; and placed towards the hinder part of the bone. The end of the femur, covered by its cartilage, presents two parts sloping in opposite directions from a more or less projecting angle, the posterior supporting the articular condyle, the anterior occupied by fibrous and muscular attachments, and invested by a thin perichondrium. The angle between the two slopes is greater in the natural state than on the macerated bone, from the projection of the anterior end of the condyle. When the cartilage is dried on the bone, the articular condyle still stands out as an oval elevation with well-marked edges.

The *synovial membrane* extends a little boyond the condyle and cavity, lining a surrounding furrow, to the outer part of which the capsular ligament is attached. The synovial membrane may be dissected off both of the cartilaginous articular surfaces; on the condyle of the femur it may even be pinched up with the forceps, and, after it is removed, a thin perichondrial layer may next be dissected off. No. V. presented, equally on both sides, an exceptionally extensive synovial surface, 2 inches in length on both tibia and femur; the breadth, 1¼ on the femur, 1⅛ on the tibia. The condyle and glenoid cavity were 1½ inch in length, the anterior ½ inch of synovial membrane lying on soft tissue, in contrast with the firm polished cartilage of the condyle.

The *capsular ligament* surrounding the cavity is thick. It was generally thicker on the deep aspect (¼ to ½ inch thick) than on the superficial (⅛ to ¼ inch), thicker at the hinder angle (¾ inch); at the anterior angle, of indefinite thickness from continuity with the tendinous insertions. In No IV., in which the cavity was small (length 1 inch, breadth ⅝) it was ½ inch thick all round. In No. V., in which the synovial cavity was large, the ligament was ⅙ inch thick along both sides, ½ inch at the hinder angle.

As noted with the tibia, the plane of this joint is oblique, so that when the tibia is pressed upwards, it rests obliquely upon the femur, but the opposition is mainly when the tibia is pressed outwards. It is at the same time a shallow ball-and-socket joint. The surfaces permit of inward and outward motion of the tibia (extension and flexion of the knee), and of gliding movements in any direction, but the adaptation appears to be for forward and backward gliding rather than for flexion and extension, and the direction of the two opposing muscular powers accords with this.

II. The Hip-Joint and the Ligaments of the Femur.

14. *Position and Movements of the Femur.*—The *position* of the head and shaft of the femur in relation to the pelvic bone is important as bearing on the arrangements of the hip-joint and the direction of the ligaments and muscles. The following indications have also enabled me to have the bones articulated and sketched in their natural relative position. The *head* generally projects beyond the outer edge of the pelvic bone. The following measurements include the cartilage on the head. The extent of the projection was, in No. III., 1½ inches; in No. II. and No. VI., ¾; in No. I., ⅝; in No, IV., in which the head is small, and in No. V., in which the head is much reduced, in each ¼ inch. In some the head is placed entirely within the edge of the pelvic bone. In No VII. it was from ¼ to ½ inch within, and the form of the macerated bone shows that it must have been so. In No. XI. also, the sharp crescentic outer edge of the acetabulum shows that the head cannot have projected. In No. VIII. (both thigh bones anchylosed), the original position of the head must have been quite within.

The position of the *shaft* is best indicated by taking its relation to the anterior border of the beak, at about their middle. The anterior border of the femur at that part is generally behind that of the pelvic bone about 1 inch, or less. The shape of the femur and the direction of the beak cause variations of this relation. In Nos. III. and VII. it was 1¼ inch; in No. IV. only ¼ inch; in No. II. they were on the same level, the beak being nearly horizontal. In No. V., on the anchylosed side, the anterior border of the femur is nearly on a level with that of the beak, while on the left side it was about 1 inch farther back.

The *movements* of the femur require to be defined, before proceeding to consider the actions of the ligaments and muscles. The movement of the hinder edge and trochanter away from the cross part of the pelvic bone is rotation inwards; the opposite, rotation outwards. The forward movement of the shaft is flexion; the opposite, extension. Carrying the distal end of the femur downwards, towards the skin, is abduction; carrying it closer to the beak is adduction. There are also gliding motions of the femur obliquely inwards and obliquely outwards, in the direction of the bone. But all of these movements are naturally very limited. The ligaments are still entire on the left side of No. I., the half grown male, and permit these movements to the following extent. (*a.*) From extreme flexion to extreme extension, the distal end of the femur has moved $\frac{2}{8}$ inch. (*b.*) From extreme adduction (contact with the beak) to extreme abduction, the distal end moves $\frac{4}{8}$ inch, but the movement is naturally much less as the femur is separated from the beak by muscles and other soft tissue. When combined with rotation inwards, the abducting movement is more free, carrying the anterior border $\frac{7}{8}$ inch away from the beak. (*c.*) From extreme rotation inwards to extreme rotation outwards, the distal end, at the posterior angle, has moved $\frac{6}{8}$ inch; taken at the middle of the posterior border of the body, the extent is $\frac{4}{8}$ inch. (*d.*) The extreme extent of the gliding movement is $\frac{1}{8}$ inch. But these movements are more free now in the dissected specimen, than when the femur was padded by the muscles, areolar tissue and fat. In the early stages of the dissections the femur could just be felt to move. In No. V., which was preserved ligamentous for a time, it could barely be felt to move on the non-anchylosed side. Anchylosis of a joint so little movable is not surprising. My impression as to the gliding movement, however, is that, in some of the specimens, it was more free than above noted in No. I.

15. *The Ligaments.*—The ligaments connecting the femur to the pelvic bone may be arranged as those of the head and those of the body of the femur, and each of these groups subdivided into the posterior and the anterior. The posterior ligaments are two in number, the greater for the body, the lesser and shorter for the head.

(*a.*) The *great posterior ligament* (figs. 11 and 16*a*), arises from the dividing ridge of the under surface of the body of the pelvic

bone, and is inserted into the posterior tubercle of the femur (trochanter) and into the border on each side of it. It is from 8 to 10 inches in length according to the size of the subject, its origin not extending on the posterior fourth of the body. Beginning as a flat ligament, it becomes gradually thicker, and in its anterior half or third, where it has left the pelvic bone, it is rope-like and as large as a thick thumb. The point of attachment of this great ligament accounts for the presence of the tubercle representing the great trochanter. The extension of the insertion a little on each side of the trochanter gives a breadth of about 1½ inch at its attachment to the femur. In No. III. the whole ligament was expanded into a broad thick triangular membrane, attached to 6 of the 9 inches of the hinder edge of that femur, the fore part of the ligament arising from the ligament of the head, with which it formed a continuous sheet. This arrangement in No. III. accounts for the absence of the trochanter on that femur. Besides checking rotation inwards and also inward gliding of the femur, the great function of this ligament is manifestly to check flexion, to resist the forward traction of the great trunk mass of muscle. In No. V., however, in which the femur on the right side was anchylosed to the pelvis, the anchylosis evidently of no recent date, the ligament was large and little if at all smaller than on the side on which the femur was movable. The traction of the muscular fibres which arise from it may have sufficed to maintain the condition of the ligament.

(*b*.) The *posterior ligament of the head* (figs. 11 and 16*b*) is attached in front to the hinder edge of the head and neighbouring part of the neck, and reaches back for 3 inches or more on the pelvic bone. In form it is a thick strap (may be ¾ inch broad and ¼ thick), increases in breadth forwards, and leaves the pelvic bone at a variable distance from the femur. It may join the great ligament by an expansion but usually there is an interval. The direction of the great ligament is forwards and a little inwards, the direction of this ligament is forwards and outwards, at last projecting beyond the pelvic bone to reach the projecting head. This ligament checks rotation inwards, outward gliding, and extension. In flexion and extension, when the body of the femur moves forwards the head moves backwards, the bone moving on its neck, hence of the two posterior ligaments, one checks flexion the other extension.

(*c.*) The *anterior ligament of the head* (figs. 11 and 16*c*) arises from the promontory about 1 inch in front of the head of the femur, and passes back enveloping the head on its under, outer, and upper aspects for a breadth of about 2 inches, like part of a capsule. The direction of its outer part is obliquely outwards, according to the projection of the head, that of the inner fibres, on the superficial aspect, obliquely inwards, the most internal running a little way on the neck where they may form a special band. The outer part checks flexion, the inner extension, the head being carried in opposite directions. The under part checks rotation outwards, and outward gliding is checked by the whole ligament except the part to the neck. In No. VII., in which the acetabulum is deep and the head placed inwardly, this ligament was in the form of a membrane 2¼ inches broad where it arose from the sharp crescentic edge of the acetabulum, and passed inwards on the superficial aspect to be inserted, 2½ inches in breadth, along the head and neck of the femur: the part to the neck was specially developed, representing probably the next ligament. When the head projects much, as in Nos. I. (figs. 11 and 12) and III. (fig. 15), the entire ligament is directed outwards.

(*d.*) *The anterior ligaments of the body* of the femur may be conveniently termed interosseous. They are two in number, one external (figs. 11 and 16*d*) passing obliquely from the promontory inwards to the femur; the other, internal (fig. 16*e*) passing from the beak obliquely outwards. The *external* arises from the inner side of the pelvic promontory, sometimes partly overlapped by the inner fibres of the last ligament, passes obliquely inwards and backwards and is attached to the anterior part of the deep surface of the body and neck of the femur, opposite to the attachment of the great posterior ligament, but reaching more externally. It is a strong ligament, square-shaped and short, averaging about 1 to 1½ inch in breadth, ⅓ in thickness, and ¾ in length. It checks extension, rotation outwards, and also inward gliding of the femur. The *internal* interosseous ligament is more expanded and membranous. Its attachment to the beak is for about 3 inches in breadth, beginning about 1 inch from the bony tip. The fibres, after slanting obliquely outwards, are attached along the deep surface of the body of the femur, at a variable distance between the anterior and posterior borders. The outer part is the strongest,

and may pass out on the neck, even as far as the head. This ligament checks extension and outward gliding. These two ligaments have a close relation to the two interosseous muscles. The internal lies either within or on the under aspect of the deep muscle, gives attachment to many of its bundles, and might be regarded as in part belonging to the muscle, but its outer part is more of the nature of a ligament. The external lies on the deep aspect of the corresponding muscle and is a strong ligament.

(*e.*) *The ligaments by which each movement is checked.*—The various movements are checked as follows. *Flexion*, by the great posterior ligament, and the anterior ligament of the head. These will be assisted by the great superficial aponeurosis and by the tibial band, yet to be described. *Extension*, by the two anterior ligaments of the body (interosseous), and by the posterior ligament of the head. *Rotation inwards*, by the two posterior ligaments. *Rotation outwards*, by the anterior ligament of the head, and the external interosseous ligament. *Outward gliding*, by both of the ligaments of the head, and by the internal interosseous ligament. *Inward gliding*, by the great posterior ligament, and the external interosseous ligament. Looking to the muscles, the direction in which movement most requires to be checked is forwards, with some inward gliding, and associated with these is the tendency to rotation inwards. Hence the great size of the great posterior ligament, which is so placed as to check these three movements.

Were the structures corresponding to the three great bands of the human hip-joint to be sought for here, we might recognise, in the great posterior ligament, the ischio-femoral band; in the external interosseous ligament, the ilio-femoral band; and in the outer part of the internal interosseous, the pubo-femoral band.

16. *The Synovial Cavity of the Hip-Joint.*—The synovial membrane is situated at the anterior part of the deep aspect of the head, extending a little way on the neck. It may reach also on the anterior part of the outer end of the head. It is more extensive on the pelvis than on the femur. On the pelvis it is elongated antero-posteriorly, on the femur generally transversely, as it covers only part of the head and extends in on the the neck. It may be as large as 2 inches by 1¼, or as small as ¾ by ½ inch, and there may be an additional synovial cavity. The membrane is distinct all round, at the reflexions and over

the articular surfaces. It can be pinched up and dissected off the cartilages, and lies loosely on the fibrous and fatty bed beyond the cartilages.

17. *The Acetabular Cartilage.*—This interesting cartilage might at first be mistaken for a growing cartilage of the promontory, but it is behind the prominence and spreads backwards and inwards to floor the articular cavity, and is evidently the cartilage of the acetabulum. Only part of it is seen when the synovial cavity is opened, appearing as the cartilaginous socket. To see it fully the thicker areolar tissue and the thicker perichondrium beyond should be stripped off. It is of an ovoid form, the more pointed end behind, and may be from 1½ to 2 inches in length, antero-posteriorly, and ¾ to 1 inch in breadth. It projects a little beyond the outer edge of the bone, and this part of it comes in relation with the fibrous edging before noticed as skirting the margin of the pelvic bone. The limits of this cartilage are seen in figs. 11 and 12, and its place on the macerated bones is seen in figs. 1, 3, and 5.

18. *The Variations and Adaptations of the Hip-Joint.*—Although in *Mysticetus* there is a head and more or less of a socket, there is not the condition of a ball working in a resisting socket. On the contrary the head of the femur generally lies out of the socket, in the position which in human surgery we would call dislocation backwards. The femur lies nearly parallel to this part of the pelvic bone, pressing close on it near the head. It is only the deep aspect of the head which can come in relation with the pelvis, and it is the outer part of the neck rather than the head which bears the pressure and which forms the pivot on which the femur moves. In this reduced condition of function we would expect to find great variation presented by the parts at the hip-joint. The more noteworthy of these, with their adaptations in the several specimens, will now be considered.

(*a.*) No. I., the half-grown male (figs. 11 and 12) will be more particularly noticed, as it afforded the best opportunity for complete examination. On the right side, the *acetabular cartilage* is fully exposed. It projects considerably outwards beyond the pelvic bone, towards the fore part as much as ½ inch; and at the same time projects downwards externally to form the edge of the acetabulum. Thus in transverse section it is prismatic; where it is thickest the attached surface and the dorsal surface each ⅝ inch, the acetabular surface $\frac{6}{8}$. The total length is 1¾ inch, but only the hinder two-thirds form the

cavity, the anterior third forming a prominence receding from the fore end of the cavity to a little way behind the middle of the promontory. The cavity is ovoid in form; length 1¼, breadth ¾ inch; concave in both directions, depth of concavity about ⅛ inch longitudinally, transversely very little; at outer edge it is slightly convex transversely. The direction of the groove of the cavity is obliquely forwards and a little inwards, in adaptation to the neck of the femur. There is thus formed a grooved cartilaginous bed adapted to receive the neck of the femur near the head, against the outer edge of which the inner edge of the head rests. The cartilage in this half-grown male is much thicker than in any of the other specimens. The extent to which this cartilage may ossify will affect the direction and form of the acetabulum on the macerated bone. Were it removed the surface of bone which supports it would recede from the level of the under surface of the bone somewhat as it does in Nos. VI. and V.; were it wholly ossified the acetabulum would not have the cup shape presented by Nos. VII. and XI., but merely the grooved prolongation behind the recurved back of the promontory which most of the specimens present.

The cartilage on the *head of the femur* is on the back part ⅛ inch thick, on the fore part ¼ inch, and receives here the anterior ligament of the head. The *synovial membrane* lines the acetabulum behind for 1 inch antero-posteriorly by ⅓ inch transversely. On the femur it covers the anterior and inner part of the deep aspect of the head, and reaches in for nearly half an inch on the neck. The synovial membrane at the neck lies on areolar tissue, this again on ligamentous tissue prolonged from the deep fibres of the anterior ligament of the head, and this on the periosteum of the neck. The exact *adaptation*, then, is that the broad oblique cartilaginous groove representing the acetabulum, receives the back of the obliquely directed neck of the femur, which is convex antero-posteriorly and fits the groove well and easily, abutting at the fore part against the cartilaginous prominence. The inner edge of the head lies exactly parallel to and closely fits the extreme fibrous edging of the pelvis which skirts the acetabular cartilage, and therefore hardly far enough in even to touch the outer edge of the cartilage except by its fore part. Hence the synovial membrane lines only the inner side of the fore part of the deep aspect of the head, besides covering part of the neck. It is therefore the neck not the head on which the femur plays, cushioned by fibrous and areolar tissue in addition to its periosteum and lubricated by a synovial membrane.

On both sides there is an *additional synovial cavity* in front of the head and concealed by the anterior ligament of the head; on the left side ⅝ inch in length, on the right side larger, but I am uncertain whether they did not communicate with the larger cavity.

As the synovial cavity of the hip-joint is exposed on the outside and behind without dividing any of the ligaments, it might at first be regarded as outside the capsule, and therefore as an outside bursa mucosa rather than a true synovial cavity of the hip-joint, but the true comparison to the fully functional joint rather is that the head in *Mysticetus* is as it were dislocated backwards between the ilio-femoral and ischio-femoral bands (see paper by the author on the

Ligaments of the Hip-Joint in Man, *Edinburgh Med. Jour.* 1858), the part of the capsular ligament between these two bands being here wanting, so that the joint is left uninclosed externally except by the aponeurosis of the muscles. The cartilage of the head of the femur thus protruded is covered, except for about the fourth part of its deep aspect where it is lined by synovial membrane, by a soft cushiony perichondrium, and surrounded by loose areolar tissue which enables it to move within the adventitious capsule formed by the aponeurosis of the muscles. The cartilage of the head therefore performs but very partially the function of an articular cartilage.

(*b.*) In Nos. II., III., IV., V., and VI. the acetabulum presents the same type as in the last, a broad groove more or less shallow, corresponding or opposite to the neck of the femur. On the macerated bones the *place of the acetabular cartilage* is seen as a rough more or less excavated ovoid or elliptical area, most pointed behind; and the place where that cartilage projected beyond the bone is marked as an eroded edge, with a rather abrupt posterior beginning at $1\frac{1}{2}$ to 2 inches behind the promontory. The acetabular cartilage was not thicker than $\frac{1}{10}$ to $\frac{1}{8}$ inch.

(*c.*) In No. III. (figs. 16 and 17) the same general adaptation is seen as in No. I., except that the acetabular cartilage does not become thick externally, the surface here becoming rounded off transversely; nor does it thicken anteriorly, there being here but a cartilaginous covering on the back of the well-recurved promontory. The synovial area on the pelvis was $1\frac{3}{4}$ by 1 inch, the cartilaginous socket only $1\frac{1}{4}$ by $\frac{1}{2}$ inch, but the whole acetabular cartilage when exposed was $2\frac{1}{4}$ by 1 inch. On the macerated bone what was the articular socket is seen on the hinder and inner part of the general area of the acetabular cartilage, close to the outer edge of the bone, which it excavates considerably. Depth of the hollow antero-posteriorly $\frac{1}{8}$ inch. Transversely it is convex. Taking in the whole area, the hollow is deeper, $\frac{1}{4}$ to $\frac{1}{3}$ inch antero-posteriorly. On the femur the synovial surface is 1 inch antero-posteriorly, only $\frac{6}{8}$ transversely. It covers the anterior half of the deep surface of the head and a little of the neck. Outwardly it does not reach farther on the head than to $\frac{1}{2}$ inch from the extreme end. The cartilage of the head is continued farthest in on the deep aspect. As far as can now be determined the inner side of the fore part of the head lay in adaptation with the outer slope of the socket and on the external bordering fibrous tissue, much as in No. I., but the projection beyond the pelvis was greater than in No. I. according to the measurement made when the parts were in connection.

(*d.*) In No. VI. the parts were so rotten that I could not be sure whether a cavity, about $\frac{1}{2}$ inch in diameter, between the fore part of the head and the edge of the acetabulum, was a synovial cavity or only a large oil cavity of decomposition. The cartilages were not examined, but the macerated bones of this not full-grown specimen show exactly where they lay. There is the same general form of both bones as in Nos. I. and III., but the head of the femur does not enlarge so much as in No. III. Its cartilaginous area ($1\frac{1}{4}$ by $\frac{1}{2}$ inch) is entirely terminal, not reaching at all on the deep aspect. The long flattened

neck is convex both ways; the last ¾ inch, which may be assigned partly to the neck partly to the head, is flat longitudinally. On the pelvis, there is a strongly recurved promontory, giving an elevation 1½ inch in length transversely, and bounding a deep non-articular hollow in which the neck of the femur lies. The cartilaginous area on this eminence is 1¼ by fully ½ inch, facing obliquely backwards, so that the cartilage must have farther deepened the non-articular hollow. But the acetabulum proper has been on the outer edge, formed by the cartilage bending back here nearly at right angles as the mark shows. This part of the area is 1 inch by ¼, facing outwards and a litle downwards. The back of the femur, where the neck and head meet, would press against this cartilaginous edging, and the whole arrangement, osseous and articular, is well-adapted to determine or to allow the various motions already defined. The cartilage-mark in this specimen might readily have been taken for that of a growing cartilage of the promontory.

The acetabulum in these three specimens may be defined as presenting the deeply-grooved type. In the next three it is comparatively shallow.

(*e.*) In No. II. (figs. 1 and 2) the bony acetabulum is very shallow (depth longitudinally about ⅛ inch, transversely $\frac{1}{20}$), the promontory being very little recurved, and is placed entirely on the under surface, not reaching the outer edge except for a little behind. Synovial surface on pelvis 2⅛ inch by 1¾; cartilaginous socket 1¼ by ⅝, but the cartilage extends ⅛ inch farther all round. This shallow cavity presents behind the middle a low mound, with a hollow before and behind it. The head of this femur is very flat, distinguishable from the neck only by its roughness and slight expansion. The head and neck on their deep aspect are quite flat antero-posteriorly and a little concave transversely. The cartilage on the end of the flattened head was ⅜ inch thick, and sent an expansion inwards on the deep surface for ⅝ inch. The macerated bone presents a corresponding roughness on the edge and deep surface, marking off what may be assigned to the head. The synovial area was 1 inch antero-posteriorly, 1⅜ transversely. About the outer half of this lay on the cartilage, presenting a rounded articular surface ⅝ inch in diameter, its outer limit ⅜ inch from the extreme outer end of the cartilage-covered head. The adaptations are exact. The femur, by its rounded articular surface on the deep aspect of the head, presents a hollow, which rests and plays on the low mound of the acetabulum. In the rotatory movements of the shaft, the fore and hind edge of the head sink into the acetabular hollows, respectively before and behind the mound. The antero-posterior extensions of the synovial sac allow the head, rotating on the mound, to move respectively forwards or backwards as the shaft moves in the opposite direction. This was on the right side. On the left side, the adaptations were nearly the same. Almost the whole of the synovial membrane on the femur was cushioned by a layer of fat, ⅛ inch thick, beneath which lay a cartilage as on the right side. On the macerated bone the head is seen to be a little longer and less expanded than on the left side and as if the cartilage had extended less inwards on the deep surface.

(*f.*) In No. IV. (figs. 5 and 6) the position is, that the much bent neck, external to the bend, lies in the shallow non-articular hollow behind the promontory, a cushion of areolar and fibrous tissue, $\frac{1}{4}$ to $\frac{1}{2}$ inch thick, intervening; and that the narrow neck and head, the latter projecting $\frac{1}{4}$ inch beyond the pelvis, can be in contact with a socket only for $\frac{1}{2}$ inch antero-posteriorly. The synovial cavity was small ($\frac{6}{8}$ by $\frac{4}{8}$ inch), oval with the long axis oblique inwards and forwards. At the femur, on the left side, it touched the cartilage of the head; on the right side, it lay opposite the anterior half of the deep aspect of the head, and partly on the neck. On the pelvis there was at first almost no appearance of a cartilaginous socket, but on removing the synovial membrane and perichondrium, a good-sized acetabular cartilage ($1\frac{3}{4}$ to 2 inches by $\frac{1}{2}$ inch) came into view, as now seen on the macerated bones. The anterior half, convex both ways, is on the hinder slope of the promontory. The hinder half, where the femur touches, is narrow, concave longitudinally, convex transversely, and slightly notches the outer edge of the bone. The bent form of the neck seems to have removed the femur from much pressure on the acetabular edge, so that no socket had been formed beyond a synovial membrane. Above the convex neck of the femur was a cushion first of areolar tissue and then of fibrous tissue, $\frac{1}{4}$ to $\frac{1}{2}$ inch thick, on which the femur moved and by which pressure of the femur against the pelvis was borne.

(*g.*) The bones of No. X. (a not very large and probably not full-grown female) were cleaned before they reached me. But the place of the acetabular cartilage is well-marked and its area closely resembles in position and form that on the macerated bones of No. IV. The promontory in front of the acetabular area is less recurved than in any of the other specimens, as if not yet fully formed. The end of the beak is incompletely ossified, but the posterior end of the body has a finished appearance.

(*h.*) In No. V. (figs. 3 and 4) a synovial sac, about $\frac{3}{4}$ inch diameter, lay on the deep aspect of the stunted head of the femur, separated from it by prolonged ligamentous fibres and loose areolar tissue. There was no articular socket, but on removing the coverings, the acetabular cartilage came into view. As the mark on the macerated bone shows, it was 2 inches by $\frac{3}{4}$ inch, commencing at the middle of the promontory, and tapering backwards; situated on the thickened outer border of the bone, facing obliquely downwards and outwards, convex both ways, except behind, where it is a little concave and narrow. This narrow part was opposite the outer and anterior part of the synovial sac. In this specimen the head, neck, and neighbouring part of the body of the stunted femur, appear to have moved on the areolar and fibrous tissue of the shallow general excavation of the pelvic bone. *Another synovial sac*, 1 inch in diameter, was found close behind the first, between the pelvic bone and the prominence caused by a greatly developed trochanter, covered by the ligaments inserted into it. It had no cartilage, and I was uncertain whether it did not communicate with the sac in front of it. On the right side, although there is old standing anchylosis of the hip-joint, the mark on the macerated bone shows that the cartilage has survived the anchylosis on the outer side, in two

patches, the posterior (1 inch by $\frac{3}{4}$ inch) opposite the anchylosed head, the other ($\frac{3}{4}$ by $\frac{1}{2}$ inch) on the back of the promontory. They correspond to where the greater part of the cartilage lay on the non-anchylosed side.

(*i.*) No. VII. (figs. 8 and 9) presents the best example of the cup shaped type of acetabulum. On the bone it is seen to be bounded in front by a strongly incurved and recurved promontory, and externally by a crescentic ridge continued from the promontory to the outer margin of the body. Besides this there is a deep excavation of the bone, bounded on the inner side by a smooth edge, more marked at the inner and fore part, least defined posteriorly where its beginning is gradual It is oval in form, about 2 inches antero-posteriorly, $1\frac{1}{2}$ transversely; greatest depth, transversely $\frac{1}{2}$ inch, antero-posteriorly $\frac{5}{8}$ inch. Speaking generally, it would hold half of a good sized hen's egg cut long ways. The only part of this great cavity lined by cartilage and synovial membrane was a small oval patch in front ($\frac{7}{8}$ inch long, $\frac{3}{8}$ inch broad). The place of this is well seen on the macerated bone, as a rough oval slightly raised platform, at the fore and outer part, its superficial edge forming part of the edge of the acetabulum. The rest of the bony acetabulum is smooth and non-articular. On the large and obliquely placed head of the femur the cartilaginous area ($1\frac{3}{4}$ by 1 inch) is placed on the end, convex both ways, but not prolonged either on the deep or superficial aspects. The synovial sac ($1\frac{1}{8}$ inch longitudinally, $\frac{6}{8}$ inch transversely) lay upon this, the deeper half between the head and the cartilaginous part of the acetabulum, the more superficial half between the head and the capsular ligament. The rest of the acetabulum was occupied by stringy areolar tissue passing between the two bones. When the bones are placed naturally together, the head is seen to be fully half sunk in the socket, and entirely so when the femur is rotated inwards, and then the oblique superficial margin of the head fits exactly the crescentic edge of the acetabulum. The outer crescentic wall quite prevents the head of the bone from gliding outwards, but the adaptations allow of the other motions already defined. Pressure of the head against the cartilage of the socket will take place most in the movements of the shaft forwards and backwards, but also in the other movements. The form of the acetabulum is compatible with much more extensive movements forwards and backwards, and of rotation, than the ligaments will allow. As already referred to, this ball and socket form of the joint was accompanied by a modification of the anterior ligament of the head into the form of a capsular ligament on the superficial aspect of the joint, assisting to confine the head in the socket. When the femur is rotated outwards, the very abrupt outer side of the trochanter, in this specimen, is seen as if adapted to fit on the inner edge of the pelvic bone.

(*j.*) The pelvic bone, No. XI., shows a less marked example of the cup-shaped acetabulum than the last. Cavity oval antero-posteriorly, $2\frac{1}{2}$ inches by about $1\frac{1}{4}$; depth antero-posteriorly $\frac{1}{2}$ inch, transversely only about $\frac{1}{6}$ inch from the want of a high inner boundary. From the well-recurved promontory the outer lip sweeps outwards and backwards in

nearly a semicircle, coming in rapidly behind, so that this large cavity is entirely supported on a bony projection external to the line of the posterior division of the pelvic bone. The outer side of the cavity rises to a sharp-edged boundary, a form which the cartilage presented by the half-grown male, No. I., prolonged and ossified, would produce. There is no indication of the cartilage having been confined to any particular part of the acetabulum. This form of acetabulum is incompatible with a projecting position of the head or with outward gliding. It is adapted to contain a large ovoid head, like that of No. VII. This characteristic specimen of the right pelvic bone of an adult female *Mysticetus* was picked up on the shore at Davis Straits.

(*k*.) The bones of No. IX. were cleaned before they reached me. The stunted condition of the beak is noted in section 4. The part which was still covered by the acetabular cartilage, now a rough depression on the bone, is seen in the drawing (fig. 7). It is situated obliquely on the foremost part of the under surface of the promontory, $1\frac{1}{4}$ inch in length, $\frac{5}{8}$ inch in breadth, and is quite flat. This area corresponds well to the back of the head of the femur. The head has the usual oblique direction, forwards and inwards, and the mark of its cartilage shows that it has been more broadly covered by cartilage on this surface than on the under surface. If this, as seems likely, was the adaptation, the femur, placed almost transversely, would conceal all the stunted beak except the root. Such a beak cannot have afforded extensive support to the body of this massive femur, but it now, in the bony state, fits pretty well against the anterior of the two deep surfaces of the prismatic body, and when the femur is moved a little backwards, the blunt point of the beak comes against a special projection on the femur, opposite the inner end of the anterior tubercle.

(To be continued.)

EXPLANATION OF PLATES XIV. to XVII. (All the figures are reduced to $\frac{1}{4}$.)

Figures 1, 3, 5, 8, and 10, show the pelvic bone, *P*; the femur, *F*; and the tibia, *T*; of the left side, from five Right-Whales; seen on the under aspect, and placed in their natural relation, except that the tibia is a little separated from the femur. Figs. 2, 4, 6, and 9, show the femur belonging respectively, to figs. 1, 3, 5, and 8 seen edge-ways from before; the surface in relation with the pelvic bone uppermost. Fig. 7 shows the pelvic bone and femur of the right side, from another Right-Whale, the femur raised from the pelvic bone. The shaded parts at both ends of the femur, and at anterior end of the beak of the pelvic bone, show the rough parts, on the macerated bones, which were covered with cartilage. The like marking on the promontory, in figs. 1, 8, and 10, are merely rough surfaces which did not support cartilage. The longitudinal line on the body of the pelvic bone in figs. 1, 3, 5, and 8, shows the position of the longitudinal dividing ridge.

Fig. 1. From Whale No. II., female 58 to 60 feet long. On the *pelvic bone*, *a*, body; *b*, beak; *c*, angle; *d*, promontory; *e*, acetabular area, partly above and below, partly concealed by head and neck of femur. On the *femur*, *g*, head, succeeded by the neck; *h*, trochanter; *i*, anterior tubercle; *k*, tibial condyle. On the *tibia*, *m* and *n*, anterior and posterior angles of the base, the articular surface not seen owing to its oblique plane.

Fig. 2. Femur of same, seen from anterior margin. The position of the anterior tubercle is marked.

Fig. 3. From Whale No. V.; female 48 feet long; *g*, very reduced head; *e*,

acetabular area, marked by dotted line. Femur of right side of this whale was anchylosed to pelvic bone at hip-joint. This fig. and fig. 1 show the characteristically broad and flat posterior end of the pelvic bone in the female.

Fig. 4. Femur of same, seen from anterior margin, and a little from under aspect, to show prismatic form of the bone, and the extreme thinness of the reduced head. The line shows the exact anterior margin.

Fig. 5. From Whale No. IV.; female about 62 feet long; *e*, acetabular area, so far as not concealed by neck of femur.

Fig. 6. Femur of the same, seen from anterior margin, showing very bent form of this femur where neck and body meet. The trochanter is seen to project upwards as well as backwards.

Fig. 7. From Whale No. IX.; a large male; *o*, rough surface on abrupt posterior end of body, for attachment of interpelvic ligament; *e*, acetabular area on promontory, marked by dotted outline; *b*, exceptionally short and narrow beak; the femur raised from natural position to show beak; *i*, very marked and rough anterior tubercle on this femur; *p*, deeply excaved end of femur which had supported distal cartilage.

Fig. 8. From Whale No. VII.; male 48 feet long. Shows head of femur lodged in a deep acetabulum, overhung by a rough reverted ledge of promontory. Characteristic distal end of femur, anterior third bevelled for muscular attachment, posterior two-thirds supporting knee-joint; the whole rough where it was covered by distal cartilage of femur. Tibia showing characteristic form, anterior and posterior angles at base, and undulations on the borders, two concavities on inner, one on outer, border.

Fig. 9. Femur of same, seen from anterior margin. The roughness on large and well-formed head shows where it was covered by cartilage. At distal end, roughness on bevelled anterior third, as seen from before.

Fig. 10. From Whale No. VIII.; male, of good size, but not of largest size; *g* dotted line showing where head is firmly anchylosed to pelvic bone. The two lines, *g*, converging behind the head, mark projecting platform of pelvic bone on which femur is anchylosed; femur of right side was similarly anchylosed; *o*, rough surface on abrupt posterior end of body for attachment of interpelvic ligament. Thick rounded form of body, characteristic of male pelvic bone, seen in the three figures, 7, 8, and 10.

Figs. 11 and 12. From Whale No. I.; half-grown male, 35 feet long. Under and upper views showing pelvic bone, femur and tibia, and their ligaments, the interpelvic ligament, and relation of penis to pelvic bone.

Fig. 11. Under view; *P*, pelvic bone; *F*, femur; *T*, tibia; *a*, great posterior ligament of body of femur; *b*, posterior ligament of head of femur; *c*, anterior ligament of head, and *d*, external anterior ligament of body of femur; *g*, capsular ligament of knee-joint. On right side, *h*, line of junction of anterior cartilage of pelvic bone; *i*, fibrous tuft attached to end of cartilage; *k*, tibial band attached to apex of tibia; *l*, distal cartilage of femur, as seen on section, dotted line marks place of junction; *m*, cartilage of head of femur, as seen on section, but cap of cartilage extended farther inwards on head; *n*, acetabular cartilage, ovoid form marked by dotted line, partly hidden by neck and head of femur; *o*, posterior cartilage of pelvic bone, limits marked by dotted lines; *q*, attachment of interpelvic ligament to cartilage of hinder end of pelvic bone; *r*, interpelvic ligament; *s*, *s*, crus penis, showing its ovoid enlargement on this aspect; *u*, corpus cavernosum after union of right and left crus; *v*, corpus spongiosum urethræ; *w*, bulb of corpus spongiosum, its hinder end concealing part of interpelvic ligament; *x*, *x*, attachment of white fibrous septum of compressor muscles along middle line of bulb and corpus spongiosum; *y*, *y*, attachment of horse-shoe septum between the compressor muscles, across crura and bulb; *z*, part of horse-shoe septum entire, showing its depth and tapering to horse-shoe raphé on surface.

Fig. 12. Upper view of same; *h*, *o*, lines of junction of anterior and posterior cartilages of this half-grown pelvic bone; *n*, part of acetabular cartilage covering narrow part of pelvic bone on this aspect; *r*, *r*, interpelvic ligament fully seen, and, continuous with it, the triangular ligament between the crura; ×, urethra, surrounded by circular and longitudinal striped muscular layers; in space between urethra and triangular ligament, are seen, on left side, three large arteries in section; *s*, crus penis, without the ovoid enlargement on this aspect; a number of arterial perforations are shown on left crus; *u*, corpus cavernosum.

Figs. 13 and 14. From same Whale as figs. 11 and 12, showing under, fig. 13, and upper, fig. 14, view of the muscles connected with same parts; and, fig. 15, a transverse section of the penis and its muscular surrounding.

Fig. 13. *a*, posterior or caudal muscular mass, attached to pelvic bone; *b*, anterior or trunk muscular mass, attached to pelvic bone, femur, and tibia; *c*, strap-like tendon, continued from flat tendinous layer concealed by the trunk mass, seen sending curved process inwards to body of femur, and another process back over head of femur to pelvic bone and caudal mass; *d*, inferior longitudinal capsular muscle, its tendon

covering head of femur, and thin continuation inwards as far as great posterior ligament, *e*; to inside of latter, the thin posterior muscle, *g*, of body of femur and tibia, seen coming from great posterior ligament, pelvic bone, and horse-shoe raphé; *h*, rectum, its circular and longitudinal muscular layers seen in transverse section; *i*, remains of anterior part of levator ani muscle; *k*, *k*, right and left rope-like muscle, retractor penis, of pale unstriped muscular fibre; *l*, *l*, great anterior compressor muscle, united to its fellow at median raphé; dotted line at its posterior origin shows how far it arises over pelvic bone; *m*, posterior compressor muscle, united to fellow by median raphé; the white semi-circular line between the two compressor muscles is the horse-shoe raphé, the superficial edge of the concealed horse-shoe septum.

Fig. 14. Upper view of same; the same letters refer to the same parts as in fig. 13; the flat tendinous layer, *c*, above the trunk muscular mass, is fully seen. Additional references are, *n*, superior longitudinal capsular muscle, seen binding head of femur on this aspect; *o* part of surface of corpus cavernosum not covered by great compressor muscle; *r*, *r*, triangular ligament, pierced by the urethra, ×; *s*. *s*, neck of bladder, surrounding urethra; several large arteries are seen in section, piercing interpelvic ligament in front of neck of bladder; *k*, rope-like muscle, seen arising mainly from neck of bladder, partly from walls of rectum, and turning forwards round hinder edge of interpelvic ligament; *t*, fibrous bundles suspending rectum; *u*, oval space between origins of the suspensory bundle.

Fig. 15. Transverse section of penis and surrounding great compressor muscle, at about 3 inches in front of horse-shoe septum. Shows the laterally compressed form of the penis within this muscle. The white part is dense fibrous tissue, enclosing, above, *v*, the erectile tissue of the fused corpora cavernosa, with a large dorsal vein or veins; and below, the erectile tissue of the corpus spongiosum, containing, near its upper part, the very distensible urethra. Above the corpus cavernosum is seen the shallow median septum between it and the dorsal raphé; below, is seen the deeper median septum, also of white fibrous tissue, between the corpus spongiosum and the inferior raphé. The section shows the great thickness of the enclosing muscle, at the sides and below. The form of the erectile medulla of the corpus cavernosum, and of the corpus spongiosum, is seen in figs. 13 and 14.

Figs. 16, 17, and 18. From Whale No. III.; female, 48 feet long; three views of under aspect, left side; showing, fig. 16, the ligaments; fig. 17, the deep muscles; fig. 18, the superficial muscles attached to the pelvic bone, femur and tibia.

Fig. 16. *a*, great posterior ligament of body of the femur (in this fig. this ligament is diagrammatic, it was naturally much more expanded, and the trochanter was, accordingly, scarcely present); *b*, posterior ligament of head of femur; *c*, anterior ligament of head; *d*, external anterior ligament of body; *e*, internal anterior ligament of body of femur; *m*, cartilage of head of femur; dotted line farther in shows outer edge of acetabular cartilage; *h*, anterior cartilage of pelvic bone; *r*, *r*, interpelvic ligament (female); *s*, antero-posterior section of this great ligament, showing its breadth and thickness; *u*, *u*, curved line on ligament, in front of which it is excavated for attachment of great genital muscular mass; dotted line shows line of inner edge of pelvic bone, concealed by this attachment of interpelvic ligament.

Fig. 17. *a*, caudal muscular mass; *c*, the flat expanded muscle and tendon seen on removing great anterior muscular mass; to right hand, a smaller stratum is seen decussating with the greater, and going to strap-like tendon; b^2, deep part of the pyramidal portion of anterior muscular mass, inserted on pelvic bone; *d*, inferior longitudinal capsular muscle; the tendinous capsule of the head of the femur, formed here by this muscle and the strap-like tendon, is seen slit open and hooked outwards, exposing the head, large in this individual, separated from the capsule by loose connective tissue; the thin inward expansion of this posterior capsular muscle is seen, in this individual, extending over great posterior ligament, *e*, and passing to nearly whole length of femur; *h*, adductor muscle of femur; h^1, external adductor muscle; h^2, internal adductor muscle; *i*, capsular ligament of knee-joint; *k*, tibial band; *l*, *l*, great genital muscular mass; *r*, interpelvic ligament.

Fig. 18. *a*, caudal muscular mass; *b*, anterior muscular mass, external and greater portion; b^1, superficial parts of pyramidal portion of anterior muscular mass, seen coming from a rounded tendon and inserted on femur and tibia; *c*, strap-like tendon, seen also in figs. 13, 14, and 17; *g*, *g*. posterior aponeurosis of femur and tibia, partly muscular in fig. 13, concealing great genital muscular mass; stronger strap-like portion of it, seen passing to tibia; *h*, aponeurosis attached to inner border of tibia; *i*, capsular ligament of knee; *k*, *k*, tibial band; *m*, perineal muscular bundles arising from interpelvic ligament; *n*, *n*, bundles of flat superficial perineal muscle, partly splitting, partly arising from, the tibial band; *o*, most anterior of the superficial perineal muscular bundles, arising entirely from the tibial band. Dotted lines in this figure show position of the beak of pelvic bone and of encapsuled head of femur.

AN INFECTIVE FORM OF TUBERCULOSIS IN MAN IDENTICAL WITH BOVINE TUBERCULOSIS. By C. Creighton, M.D., *Demonstrator of Anatomy in the University of Cambridge.*

(*Continued from page 57.*)

VI.—The Disease in the Lungs—*Continued.*

Giant-cells were discovered by Virchow in the tuberculous nodules of the bovine species ten years before they were described for tuberculosis in man;[1] and the giant-cells that Virchow described and figured are of the largest and most perfect kind. The earlier discovery of giant-cells in the bovine nodules was doubtless owing to their greater prominence in the bovine disease. Giant-cells are characteristic of bovine tuberculosis, whether as it exists in the bovine animals themselves, or as it is directly communicated to man, on the broad ground of their number and perfect type. By perfect type I mean great size, regular marginal arrangement of nuclei, and broad central area of granular protoplasm; for in those particulars they come near to forming that which they always tend to form, viz., portions of new blood-vessels. Along with the giant-cells of large size and perfect type, the other cells of the nodule frequently have the character, of large epithelial-like cells with one or more nuclei (as in fig. 15 Plate VI.) The nodules of the serous membranes, the actual "pearls" of the bovine disease, afford perhaps the most numerous and the most perfect examples of the giant-cells, and of the associated large epithelial-like cells. In the three cases of the above series, from which I preserved specimens of the large flat tubercles of the serous membranes, the number and the uniform characters of the largest giant-cells were very noticeable in the marginal zones of those tubercles that were caseous in their interior, and the large epithelial-like cells, with one or more nuclei, were found with equal uniformity in the smaller and more recent centres of new formation. So much did the numerous giant-cells,

[1] Virchow's *Archiv*, vol. xiv. (1858) p. 47.

with marginal nuclei and free protoplasmic interior, associated with groups of epithelial-like cells in the younger tubercles, seem to me, after examining these cases, to characterise a specific form of disease, that, when I found a new formation in all respects the same in sections of a tuberculous testicle, which I was using for my class of pathological histology, I felt much disposed to conclude that the particular tuberculous testicle must have come from a case of the communicated bovine disease.[1]

A similar conclusion as to the giant-cells of bovine tuberculosis may be gathered from the observations of Orth on the tubercular disease which he induced in rabbits by feeding them with nodules from tuberculous cows.[2] As Professor Orth gives special attention to the microscopic characters of the disease which he induced by experiment, I shall include here a brief summary of his experiments, by way of supplement to the observations of Gerlach noticed in Section III. (p. 23). It is no doubt true that Orth does not clearly assert the identity of the induced disease in the rabbit with the original disease in the cow. He points out that the nodules on the pleura were not pedunculated, nor were they joined together like strings of pearls, in the manner characteristic of the bovine disease. In another place he remarks on the absence of calcification, also a characteristic of the bovine disease. But pedunculated nodules, and nodules strung together like pearls, are by no means invariably found in the tuberculous cow, nor is calcification present in every case, and still less is it the only form of degeneration found in the nodules. Both the pendulous form of the serous-membrane nodules and the calcareous degeneration appear to depend on the age of the new formations. The disease induced by experiment is in every case a more acute

[1] The testicle was obtained, along with other organs, from the *post-mortem* room of Addenbrooke's Hospital on 15th August 1878. The patient, aged 25, a navvy, had suffered for four years from weakness in the back (ending in caseous disease of lower dorsal and upper lumbar vertebræ), which came on immediately after an attack of scarlet fever. The testicles were not observed to enlarge until three months before he died. The lungs, liver, spleen, and kidneys contained tubercles. The brain contained numerous very large nodules, up to the size of a hazel-nut, both in its substance (cerebellum especially), and also adhering to the branches of the anterior cerebral and middle cerebral arteries. It is to be observed that the disease was a sequel of scarlet fever.

[2] Orth, "Experimentelle Untersuchungen über Fütterungs-tuberculose."—Virchow's *Archiv*, vol. lxxvi (1879) p. 217.

process than the spontaneous bovine disease; as measured by time, the disease in the cow is more chronic by several years. It ought to suffice for a proof of identity if one finds what Gerlach, in the passage above quoted, calls "the beginnings of Perlsucht." Orth, however, goes so far as to speak of the disease in rabbits as "Kaninchen-Perlsucht," and I would in like manner be content to establish the foregoing cases in man as cases of "Menschen-Perlsucht." But when due allowance is made for the induced disease being a more or less acute infection, and the original disease one of several years' standing and gradual progress, it must be admitted that the disease which Orth found in the infected rabbits has sufficient points of identity with the specific disease in the cow.

Experiments of Orth.—There were two series of experiments. In the first, eleven rabbits were employed, four of them being simply kept beside the others without being fed with the tuberculous substance, as a control on the experiments; the remaining seven were fed with fresh tuberculous substance from the cow, and only two of these took the disease, the result of the experiment in the other five being negative. The second series of experiments proved to be much more important. Four rabbit-hutches were used, and in each were placed five rabbits. One rabbit in each received fresh tuberculous substance from the cow, and another the same substance boiled; one rabbit received fresh caseous substance from the human body, "from the firm caseous masses of caseous pneumonia," and another the same substance boiled; and the fifth rabbit in each box was simply allowed to live beside the others, so as to control the experiment. The remarkable result of the experiment was that all the four rabbits fed with fresh tuberculous substance from the cow took the disease, as did also three of those fed with the same substance boiled; but all the rabbits fed with caseous masses from the human body remained unaffected, as did also the four unfed rabbits used for control. The animals were made to swallow pieces of the substance introduced into the mouth by a blunt-pointed forceps, and there was no wounding of the mucous membrane. Of the bovine material, each rabbit received at one time five or six pieces as large as peas. Those of the first series were fed twenty-seven times on almost consecutive days; those of the second series were fed ten times on consecutive days, and a certain number of them were again fed after a long interval. The animals were kept alive for various periods. Those that were killed or died after a minimum period of four and a quarter months, ten in number, were all tuberculous except two, while of those that died or were killed sooner, only one was tuberculous, and that was a rabbit that died after three months. In three rabbits fed with bovine tubercles, which were killed within the first two months, there was no trace of infection. The nodules in the successful experi-

ments were found in the whole of the digestive tract, in the lymphatic glands, in the lungs, on the pleura and peritoneum, in the kidneys, in the liver, in the spleen, in the choroid, and (in a single case) in the iris, brain, and testicle. I shall refer to the new formations in the lymphatic glands and in the intestine under the respective headings. In the present section I shall quote the observations relating to giant-cells in the serous-membrane nodules, and some remarks on the lung lesion.

"In one of the larger nodules on the pleura," says Orth, "the giant-cells were so abundant that, in a field of the microscope under Oc. 3 and Obj. 4 of Hartnack, several dozens of them could be counted. They gave here the impression of being the centres of lamination round which the smaller, but still large, epithelioid cells had grouped themselves. At the edge of the nodule, giant-cells occurred either isolated or merely with single epithelioid cells near them" (*l. c.* p. 230). Elsewhere, Orth describes the largest giant-cells as having for the most part a regular marginal circlet of nuclei and a free central space of finely-granular protoplasm.

The largest giant-cells, and those with the most regular marginal arrangement of their nuclei, are found mostly in the periphery of nodules that are more or less caseous or otherwise necrosed in their centre. The smaller multinuclear cells, showing all gradations down to the epithelial-like cells with a single nucleus, are found in such centres of new formation as I have drawn in fig. 15, Plate VI. The figure is taken from the thickened tissue in or near the floor of the healed ulcer of the ileum in Case 10. Such are the tubercle-centres that Orth found very uniformly in the infected rabbits. In the pathological handbook of Perls, the characters and the grouping of the cells therein shown are said to be distinctive of the tubercle-nodules of the bovine species.[1] But the epithelial-like cells of tubercle are claimed, on the other hand, by Rindfleisch as the "specific product of scrofulous tubercle." The large epithelial-like cell is, he says, "a histological acme which the growth perhaps in all cases strives after, but does not always attain to." The woodcut which Rindfleisch gives of them is drawn from the floor of a fresh tuberculous ulcer of the ureter. In like manner, Schüppel found them in a number of cases of tuberculosis of the lymphatic

[1] Perls, *Lehrbuch der Allgemeinen Pathologie.* Stuttgart, 1877. Vol. i. p. 399, and fig. 96.

glands, as well as in the new formations from a tuberculous cow, and he adds to his description of this kind of tubercle the unlikely theory that the giant-cell is the central point in the formation of the tubercle, and that the epithelial-like cells that surround it are budded off from the central and parent giant-cell.[1] The tubercle composed largely of epithelial-like cells has thus already acquired a footing in human pathology. Rindfleisch would even make the large epithelial-like cell the specific cell of tubercle, or, as he says, of "scrofulous tubercle." For the specific cell of "scrofulous tubercle," I should be inclined to substitute the specific cell of "bovine tubercle," although I would not rest the specificity of the disease on the form of cell. I shall endeavour to show in the next chapter that the occurrence of the large epithelial-like cells in tuberculous lymphatic glands, as originally described by Schüppel, is on the whole in favour of their being characteristic of the bovine disease.

Although my contention is that the tuberculosis of the bovine animals is a specific disease, and that the cases herein recorded are identical with it both in general and naked-eye characters and in points of minute structure; yet I would rest neither the specificity of the bovine disease, nor the identity with it of the disease in man, upon the occurrence of elements such as giant-cells. Nothing that I can say on the futility of looking for the specific marks of a disease with the microscope would be so illustrative or so weighty as the remarks of Dr Wilson Fox, made before the Pathological Society of London in a discussion on Tubercle in 1873.[2] Giant-cells, like lymphoid cells and other embryonic forms of cells, have become the common property of many kinds of growths and of a variety of processes, both normal and diseased. They have been found in the nodules of lupus, in the nodules of the nasal mucous membrane in glanders, in syphilitic gummata and sores, in granulations, &c. I lately found (and hope soon to give an account of) remarkable instances of giant-cells in the wall of a dermoid cyst of the ovary and of a subcutaneous dermoid near the orbit, where they play the curious part of rudimentary follicles for the new-formed hairs. They may well occur in tuberculous formations that have originated in

[1] Virchow's *Archiv*, vol. lvi. (1872) p. 46.
[2] Wilson Fox, *Pathological Transactions*, vol. xxiv. (1873) pp. 366–70.

the body independently of a direct infecting virus from without, just as they occur in anæmic granulations. Nothing can be made of giant-cells for differential diagnosis unless their significance be kept in view. I have already expressed the opinion that one of their meanings, both in normal and in morbid processes, is difficult vascularisation of the new growth, and I have as yet had no reason to think that their obvious significance in the placental new formations is not a good physiological clue to their significance elsewhere.[1] Their numbers and their often highly-developed forms (with marginal nuclei) in the bovine nodules are in proportion to the relatively high vascularity that these growths attain to, and the occurrence, in the same disease, of centres of epithelial-like cells with one or more nuclei, has its exact analogy as a part, if not a perfectly intelligible part, of the vaso-formative process in the placenta, as represented in fig. 16, Plate VI.

It is the tendency towards complete vascularisation that gives the nodules of the bovine disease that affinity to sarcomatous growths which Virchow has specially drawn attention to. In the 13th experiment of Gerlach (quoted on p. 24) the lungs of the animal (a lamb) contained large nodules of grey colour and medullary consistence, which, he says (see p. 24), had "a certain resemblance to small sarcomas; and the same large nodules came still further *to resemble the new formations of Perlsucht*, in that even capillary vessels appeared in them." The nodules contained no giant-cells, but they contained capillary vessels.[2] The same

[1] This Journal, vol. xiii. (1879).

[2] In August 1880 I received from Dr Bradbury portions of the lungs from a case in his private practice, which is of interest in the present connexion. The patient, a woman, aged about sixty, had come to Cambridge for advice, and the symptoms at that time pointed to rheumatism. There was, however, no rise of temperature. On returning to the country, she died somewhat suddenly. There was a freely movable nodule, about the size of a hen's egg, under the skin above the clavicle, probably an enlarged lymphatic gland. Both lungs were occupied throughout with greyish-white nodules, of the average size of a hazel-nut, definitely rounded and circumscribed, and readily shelling-out from the lung substance. On section, the surface was somewhat fibrous. In the portions of lung that I obtained there were also several smaller nodules, not larger than peas, and these were darker in colour, and, as it proved, hæmorrhagic. On the sharp margin of the lower lobe I found the long and solid cord-like outgrowths that I have elsewhere described, as well as faintly-marked leaf-like outgrowths on the concave pleural surface of the base. The microscopic examination of the larger nodules showed them to be composed of spindle-shaped or rod-shaped cells, which were regularly arranged in close decussating bundles, showing alternately, in the section,

observation applies to the small tubercle that I have figured on Plate IV. fig. 12; it contains even numerous vessels, but no giant-cells, and it may be said of many other nodules in the series of preparations that the giant-cells begin where the vessels cease, and that the necrosis or caseation exists where the giant-cells have been powerless to avert it. Rationally interpreted as vaso-formative cells, giant-cells are distinctive of bovine tubercles, from their numbers and their highly-developed type; and the epithelial-like cells, passing into multinuclear cells (fig. 15, Plate VI.), are equally characteristic of a decided tendency towards vascularisation, on the analogy of the perfectly similar epithelial-like cells passing into multinuclear cells that may be seen co-operating in the vaso-formative processes of the placenta (fig. 16, Plate VI.)

To return more particularly to the nodules in the lungs, I have spoken of them hitherto as purely interstitial connective-tissue growths. In some of the cases they certainly are uncomplicated interstitial tubercle-conglomerates, as in Cases 2 and 3, from which drawings (fig. 7, Plate III.; figs. 11 and 12, Plate IV.; and fig. 13, Plate V.) have been made; in Case 2 the air-vesicles near the nodules were either empty or they contained a number of red blood-corpuscles. But in four other cases in which whitish masses were found in the lungs, there occurred, besides numerous

the transverse view or the longitudinal view of the spindle-shaped cells. The forms of the cells and the interweaving of the bundles corresponded to what one finds often in sarcomatous tumours, and to the stroma of the normal ovary in some animals. Here and there in the microscopic section, there occurred regular round or oval spaces lined as if by an epithelium of small cubical cells. In some instances the appearance was that of giant-cells with the nuclei all on the margin, and the central substance more or less fallen out. (I had previously found this peculiar appearance in an extensive sarcomatous tumour growing from the fascia lata of the thigh in a boy aged twelve, and I referred to it in a paper in the *Journal of Anatomy and Physiology*, April 1880, on "Illustrations of the Pathology of Sarcoma" (p. 321).) The peripheral portions of the nodules were penetrated with numerous large blood-vessels full of blood, and the smaller nodules differed from the larger in having their spindle-shaped tissue as if infiltrated with blood. It was nothing but the sarcomatous character of the nodules that prevented me from classing the case among the twelve that I have reported; the naked-eye characters, and especially the peculiar outgrowths from the pleura, were all in favour of that view. Taking the movable nodule above the clavicle to be a lymphatic gland, there was nothing found that could be called a primary tumour, from which the nodules in the lungs might have proceeded, and the existence of the latter is most easily explained on the hypothesis of an infection from without.

interstitial tubercles, a wide-spread pneumonic condition of the air-vesicles. In Cases 5 and 6, which had the remarkable closed vomicæ at the apex (fig. 9, Plate III.), the thick belt of tissue forming the walls of the vomicæ was the ordinary embryonic connective tissue found in the interstitial lung-nodules, and giant-cells were not wanting; but the neighbouring air-vesicles were occupied by pneumonic or inflammatory products, the croupous form, with numerous threads of fibrin, being on the whole more conspicuous than the catarrhal form of swollen and detached epithelial cells; and I would even admit that some, if not many, of the whitish nodules that were seated as if on the periphery of the closed vomicæ, or in the intervals between them (see fig. 9), corresponded to circumscribed groups of air-vesicles within which the exudative or catarrhal products had undergone necrosis. But Case 5 was, in other respects, as I have already said, "one of the most complete cases of the series;" and in Case 6 I found, elsewhere in the lung, uncomplicated interstitial tubercles in the tissue surrounding a large branch of the pulmonary artery. Again, Case 8 was complicated with a very general catarrhal condition of the air-vesicles all round the giant-cell tubercles, which did not, however, amount to a nodular formation; and the same remark applies to Case 10, in which the tubercles were very small and translucent. I have already mentioned that in Case 12 there were, in one of the lungs, two large and sharply-defined masses of grey hepatisation, one of them wedge-shaped. It is necessary to particularize these occurrences of coexisting pneumonia, so as to avoid appearing to ignore them.

On this point of coexisting pneumonia, the observations of Orth on the condition of the lungs, in the rabbits which he succeeded in infecting with the bovine tuberculous substance, are of the most direct interest. The infection attacked the digestive tract and lymphatic glands in most cases, and almost invariably the lungs and pleuræ, peritoneum, kidneys, &c. The nodules in the lungs varied much in size, some being as large as a cherry. Tracts of air-containing lung tissue, usually of a deep red colour, occurred between the solid circumscribed nodules, the larger of which were grey in the periphery and opaque yellowish in the centre. The composition of the large nodules out of a number of smaller ones was very clearly made out round their

edges. In several lungs small cavities had resulted from the softening of the caseous masses, like the vomicæ of the human lung, and, he might have added, like the still more numerous vomicæ of the bovine lung. To meet the objection that the lung nodules were "nothing more than simple miliary pneumonias," he had a special investigation of them made under his direction, by one of his pupils, of which he gives the main conclusions. In the lungs, just as in other organs, there occurred nodular new formations which did not arise from the filling up of the alveoli; they were in parts of an obvious reticular structure, often contained very large cells, and, in several lungs, fine examples of giant-cells. They were nodules, therefore, that corresponded in all essential respects with those which he had previously described for the digestive tract and the lymphatic glands, as well as with those which he subsequently describes for the serous membranes, kidneys, and other organs; and they could on no account be regarded as "simple miliary centres of pneumonia." He continues :—"No doubt such undoubted tumour-nodules make up only the smallest part of the changes in most of the lungs; coexisting therewith, in greater amount, are inflammatory appearances, especially in the alveoli; in their lesser degrees these consist of swelling of the epithelium, whereby the alveoli return to an embryonic character, but in some cases the inflammatory changes are so extensive that wide-spread pneumonic hepatisations result. In consequence of this it is often quite impossible, in the case of the larger centres of disease, to decide whether any, or how much, of the changes present should be attributed to the formation of nodules. Just as in chronic inflammations of the human lung, and even in the chronic pneumonias of rabbits (Friedländer), there occurred manifold changes both in the walls of the bronchi and also in those of the vessels. In the one situation there was for example, a typical growth of epithelium (Friedländer), and, in the case of the vessels, changes in the adventitia and in the intima. The changes in the vessels are partly referable to obliterative endarteritis, but they are also, in my opinion, partly to be considered tuberculous. The tubercles are seated partly in the adventitia, and have pressed forwards towards the intima; but they are in part confined to the latter, and are to be regarded as primary tubercles of the intima."

It is not part of my present purpose to go into minute questions of the histogenesis of the lung nodules, how far they are perivascular or peribronchial, or how they are related to the lymphatic system. This subject has been ably treated of and illustrated with admirable drawings by Klein in this country, in connexion with the lung-nodules in Guinea-pigs, which he describes as those of "artificial tuberculosis."[1] The same minute points of histogenesis might equally arise in connexion with the lung-nodules of glanders. There may well be points in common for the various kinds of pulmonary infection, when we come to the ultimate histogenesis; but over and above those matters in which infective processes in the lung agree, there are points, microscopic and other, special to each. It is with the latter that I have chiefly occupied attention in this section; and I would further stipulate that even those characters in the lung which I have endeavoured to single out as special to the bovine disease, may not be taken by themselves, but always in connexion with the less ambiguous associated formations on the serous membranes, described in the preceding section, and with the implication of the lymphatic glands to be described in the section immediately following.

VII.—The Condition of the Lymphatic Glands.

Lymphatic glands in the human body that are, to the naked eye, simply enlarged, and caseous or calcareous, are by no means likely at the outset to prove distinctive of that specific disease which I have already attempted to identify by means of the serous-membrane and pulmonary lesions. Caseous lymphatic glands have the misfortune to be so common, they enter so largely into the everyday observations of practitioners, that any attempt to discover in them traces of an outlandish specific disease cannot but appear, on the face of it, to be unlikely. Even those cases in which general tuberculosis has been found associated with caseous lymphatic glands, are subject to so fixed and conventional an explanation that we seem to have reached the ultimate truth about them. When a patient dies of general tuberculosis, it is the caseous bronchial or mesenteric gland that

[1] Klein, *The Anatomy of the Lymphatic System.* Part II.—"The Lung." London, 1875.

we point to with conclusiveness as the source of the tuberculosis. No matter how unaccountable the disease may have been in its onset, as in so many cases of general tuberculosis in previously healthy children; if the *post-mortem* examination discovers a caseous gland at the root of the lung or in the mesentery, the chances are that the practitioner will go away satisfied, feeling that the case has at least ranged itself beside many more of the same kind, and has somehow become a good deal clearer to him. There are naturally hypotheses current to explain the connexion of the caseous gland with the disseminated tuberculosis. The gland had undergone a simple swelling or hyperplasia, owing to some irritant process, such as catarrh, going on in the locality to which the glands respectively belong; but physicians would be sometimes puzzled to discover that there had actually been any sufficient preceding catarrh or local irritation, such as the hypothesis requires. Next, the swollen gland, instead of returning to its normal state, becomes caseous. That peculiar degeneration is accounted for by the scrofulous disposition of the individual; but there is no doubt that the scrofula is in many cases an afterthought, and that the patient had not shown the usual manifestations of scrofula during life. Lastly, the caseous detritus of the swollen gland is absorbed, and it is the absorption of it that has led to the disseminated tuberculosis. But our satisfaction with this familiar explanation would diminish if it were shown that the caseous gland itself is full of tubercles, just as the lungs are full of them and the serous membranes covered by them. That, however, is the conclusion that we are led to from the examination of the lymphatic glands in the cases above recorded. They contain the same tubercle-nodules that occurred on the serous membranes and in the lungs. It is probable that the formations in the lungs, in most cases, come last in point of time; but, in cases where the serous membranes and lymphatic glands are both implicated, it is practically impossible to say which of those two had been first affected. In the tuberculosis of the bovine animals themselves it is usually said that the serous-membrane eruption appears first, and then the nodules in the lymphatic glands. It is also said of the bovine disease that the lymphatic glands are little affected when the serous membranes are extensively covered by nodules, and *vice versa.*

In the cases in man, there is probably a certain sequence observed in the spread of the infection within the body, although that sequence may not be the same in all cases. But, whatever be the order in point of time, there is sufficient identity of structure in the nodules on the serous membranes, in the lymphatic glands, and in the lungs, to show that these formations are all co-ordinate as the effects of a common cause, and their morphological characters are such as to point to the specific disease which is indigenous in the bovine species as being the source outside the body from which the common virus has issued.

The lymphatic glands were observed to be implicated in more than half the cases. In Case 10, which had by far the most abundant eruption of the large flat tubercles on the peritoneum, the abdominal lymphatic glands appeared to be perfectly normal. In Cases 1 and 6, their condition is not noted; in Case 4 there was near the root of the lungs a large quantity of whitish substance like a diffluent tumour, which I took to be the bronchial glands, but did not preserve for examination. In Case 8 the bronchial glands were merely swollen and soft, and a microscopic examination did not reveal any well-defined tubercles; and in Case 12 no obvious change of the abdominal or thoracic lymphatic glands was observed. In all the other cases lymphatic glands were found which proved, on microscopic examination, to contain tubercles (with giant cells, &c.), and some of them contained isolated round nodules visible to the naked eye, or conglomerate tubercles. The most remarkable cluster of glands was found hanging down from the portal fissure in Case 5 (see notes of cases), and the bronchial glands in that case showed also the same condition. A coloured drawing of one of the latter in section is given in Plate III. (fig. 10); the section shows a number of yellowish round nodules, in size up to that of a pea, each with a well-defined margin or apparent capsule. The microscopic appearance of the same gland is given in fig. 14, Plate V.; the figure shows four distinct tubercles occurring close to each other in the follicular tissue. The tubercle on the left side of the figure is of the reticular sort, with a large giant-cell near the centre; the other three are more advanced towards caseation, though in varying degrees; and it is worthy of note that the uppermost tubercle was caseous throughout its whole

extent, and that the only evidences of vitality in it were the two large giant cells which lay at its extreme periphery and in immediate contact with the neighbouring follicular tissue. In Case 11 also, where the whole abdominal and thoracic glands were affected in various degrees, a number of separate round centres could be seen with the naked eye in most of the glands, and some of these centres were so much softened in their interior as to resemble small abscesses. But in the other four cases the glands were for the most part caseous throughout almost their whole extent. It was only the thickened capsule and periphery of each gland, and the tissue joining the several glands, that retained their translucency and vascularity; and it was, generally speaking, only in these belts of translucent tissue that the traces of the small ultimate tubercles could be satisfactorily seen. Such less opaque peripheral portions of tissue contained giant cells lying among embryonic connective-tissue cells, and there could be little doubt, on the analogy of the appearance shown in the upper part of fig. 14, that the marginal belts of tissue containing giant-cells and the other component elements of tubercles, were the peripheral portions of tubercle conglomerates which had become caseous throughout the greater part of their substance. In glands where the caseation is well advanced, the traces of tubercles will hardly be found elsewhere than in the more translucent peripheral belts of tissue; and that is perhaps the reason why Trasbot, writing on the disease in the bovine animals, asserts that the lymphatic-gland tubercles develop in the connective tissue that unites the several glands in a cluster (see p. 19).

Thus far the subject has been the detection of tubercles in lymphatic glands. Their histogenesis has also to be noticed, though very briefly. It is no doubt in the follicular tissue of lymphatic glands that the small ultimate tubercles first arise. Schüppel pointed that out, and it may be seen at a glance in sections of a gland in a tolerably early stage of invasion (fig. 14). The small circumscribed tubercles in the figure appear to be minute and sharply-defined portions of the follicular tissue undergoing a series of transformations, which may be otherwise described as a series of steps in the resistance to the genera. necrosis that will finally overtake the tubercles, all and singly

The giant cells and the epithelial-like cells associated with them are, as I have already argued from a perfect analogy in the department of physiology, the evidence of difficult vascularisation in a hyperplastic tissue. They are the only indications of vasoformative activity within the tubercle nodules, and their activity appears to be for the most part abortive.

While there are these evidences within the tubercle-nodule that its tissue is cut off from the general blood supply of the part, and that its elements, as if for self-preservation, are attempting to form themselves into new blood channels, it is a striking fact that the neighbouring tissue of the lymphatic gland is traversed in all directions by wide blood-vessels over distended with blood. Two or three such vessels are seen in the midst of the follicular tissue occupying the left upper corner of fig. 14. The appearance occurs with much uniformity in the series of affected lymphatic glands. If the vessels are nothing more than the pre-existing capillaries, these at least are enormously dilated, and in some cases the dilatation is so great that actual blood-filled sinuses or lucunæ result. The appearance of large blood-vessels traversing the follicular tissue, as in fig. 14, is not usually met with in the examination of healthy lymphatic glands.

Besides containing undoubted instances of small round tubercles, sometimes united (as in fig. 10, Plate III.) to form conglomerates, the lymphatic glands were distinguished by their occasional great size and their tendency to calcareous degeneration. The most remarkable instance of the two latter characters occurred in Case 9, where the mesentery contained one enormous round mass, as large as a hen's egg and as heavy as a stone; near it were a number of quite small mesenteric glands, also calcified throughout. Calcification was also observed in several of the abdominal glands of Case 11, in the very striking form of well-defined calcareous spots in the very centre of the gland. In the extensive cluster of portal glands in Case 5, one or two of which were as large as a hen's egg, calcification could not be asserted positively, but the glands were of extreme hardness, creaking under the knife.

Two characters that are often found in the lymphatic glands in bovine tuberculosis are the great enlargement and the tendency to calcification. But greatly enlarged and calcified lym-

phatic glands are not always found in the bovine disease; the glands may be only moderately enlarged, and the degeneration may be simply caseous. A third and more constant character of the bovine disease is that the lymphatic glands contain distinct small tubercles in their substance,[1] and that these are often united to form tubercle-conglomerates visible to the naked eye. The same characters were noted by Gerlach and by Orth in the kind of bovine tuberculosis which they induced by experiment. I have already quoted from the evidence of Gerlach (p. 23), and the following is from that of Orth:—"Lymphatic glands were found in seven out of nine cases of the induced disease, containing numerous yellowish caseous centres; in one case, a yellowish nodule of exceptional size enclosed in its centre a small spot of calcareous substance. In the microscopic sections, there appeared a grouping of the cells to form minute tubercle-like nodules. The cells composing the nodules were, generally speaking, several times larger than colourless blood corpuscles, with a large and sharply-defined smooth nucleus and an extensive body of cell substance, and, in fact, meriting the name of 'epithelioid' cells. Among them there lay, in several glands, giant-cells, round or elongated, often with broad or delicate processes, and with many nuclei often arranged in the form of a marginal wreath. The size of these cells, as well as their number, varied much, and it was easy to trace a succession of them down to the simple epithelial-like cells. There was often seen, round the largest giant-cells, a number of smaller but still multinuclear cells, which, again, were succeeded by the simpler epithelial-like cells."[2]

Are these characters of the lymphatic glands in man good evidence of the disease being the communicated bovine tuberculosis? The difficulty of maintaining the specific quality of the bovine disease and the strict identity of the cases in man is nowhere more directly felt than here. Professor Schüppel published, in 1871, a work entitled *Untersuchungen über Lymphdrüsen-Tuberculose*, in which he gave an account of the minute anatomy of the caseous or scrofulous glands in forty cases ob-

[1] Schüppel, Virchow's *Archiv*, lvi. (1872), p. 52.

[2] Orth, "Experimentelle Untersuchungen über Fütterungs-Tuberculose."—Virchow's *Archiv*, lxxvi. (1879), p. 223.

served at Tübingen in the space of about two years. In six of the cases the glands were extirpated by operation; in five fatal cases, all of them of young children, the lymphatic-gland affection was the chief feature and there was no general tuberculosis; twenty-one of the cases may be taken as cases of more or less generalised tuberculosis; five were old museum specimens; and of the remaining three, one was a case of retro-pharyngeal abscess, one a case of pyæmia, and one a case of "fibrous cancer" of the pylorus. The notes of the cases are limited for the most part to the morbid anatomy, and some of them are too fragmentary for judging of the case as a whole. In all of these glands (including, strange to say, the greyish-white fibro-caseous glands lying along the greater curvature of the stomach in the case of fibrous cancer of the pylorus) Schüppel found tubercles either commencing or in full development. From their study he arrived at that definition of tubercle which Rindfleisch adopts for "scrofulous tubercle," and which I have several times referred to. The tubercles contained at least one large giant-cell, usually in the centre, with epithelial-like cells in large numbers round about; they are precisely the same kind of tubercles that I have drawn in fig. 15, Plate VI. from the subserous thickening near a healed intestinal ulcer in Case 10.

In 1872 Professor Schüppel published an investigation on "The Identity of Tuberculosis with Perlsucht."[1] The paper contains an account of the microscopic structure of nodules from a tuberculous cow, chiefly of the large flat tubercles on the serous membranes, and, more briefly, of certain selected nodules in the lung, and of the nodules in a bronchial gland. The microscopic characters of the tubercles were practically the same in the three situations, although it is of the serous-membrane nodules that the full description is given; and those characters were precisely the same as he had described, the year before, for the caseous or scrofulous, and, in reality, tuberculous, lymphatic glands in man. But Schüppel goes much further, telling us, in so many words, that he had satisfied himself, by numerous examinations, that just the same kind of tubercle occurred also in all the other situations in which he had found tubercles in the human body; and he enumerates the lungs, the tracheal mucous membrane,

[1] Virchow's *Archiv*, lvi. (1872), p. 38.

the liver, the spleen, the testicle, the bones, the synovial membranes, the sinuses of tuberculous osteitis, tuberculous pericarditis, and tuberculous ulcers of the intestine.[1] After this sweeping stroke of identity we naturally look for a strong conclusion. But the conclusion merely is—"We are thus justified in designating Perlsucht as that anatomical form in which tuberculosis presents itself in bovine animals" (*loc. cit.* p. 53). This appears to be little more than the truism that the particular disease of cows and oxen which we call bovine tuberculosis is a form of tuberculosis affecting that species, just as there is a tuberculosis of the human species. Elsewhere, he speaks of the tubercle which he histologically defined, as being the "Urform" or primitive type of tubercle, reappearing, as it were, both in the bovine and in the human species. But if that is all that the "identity of tuberculosis and Perlsucht" comes to, it is perhaps a not very profound discovery; bovine tubercle is like human tubercle much as the river in Macedon was like the river in Monmouth. All that Professor Schüppel can be got to say is, that "the result of his histological investigations cannot prejudice the question of the specificity of tuberculosis, or the question of the ætiological connexion between human tuberculosis and Perlsucht."

Not only is Schüppel's identity, on his own showing, quite harmless and neutral, but it is from the outset too narrow in its scope to be of any use. At the beginning of his paper he recognises frankly the striking naked-eye differences between the bovine tuberculous disease and tuberculosis in man. Chiefly following Virchow, he observes that Perlsucht is always primary on the pleura and peritoneum, whence it invades the lymphatic glands of the thorax and abdomen; more rarely it extends to the lungs, liver, and Fallopian tubes. Further, the pearl nodules, at least those of the serous membranes, are only to a small extent in the form of (miliary) tubercle, "as we see it in man;" for the most part, they are extensive nodules of the size of a pea, a cherry, or a potato, and these nodules have more resemblance to a fibrous tumour than to large conglomerates of tubercles, "as they appear in many organs in man." Still further, the larger pearl nodules of the pleura or peritoneum are not situated in or under the serous membrane, but they develop from a new-

[1] *Loc. cit.* p. 45.

formed mass of tissue, finely villous and highly vascular, which grows out above the free surface of the serosa, and they are not unfrequently connected with the serosa by a thin stalk of connective tissue. "In spite of these differences," says Schüppel, "I do not hesitate to declare Perlsucht and tuberculosis to be anatomically the same." But these naked-eye differences are just the characters upon which veterinarians rest the specific quality of the bovine disease, and Virchow maintains its separateness partly on the same grounds. Another instance of the tacit disregard of striking differences is furnished by Carswell. Fig. 4 of Carswell's first plate illustrating "Tubercle" is a large drawing of the lung of a tuberculous cow, showing, in the section, a number of yellowish-white nodules, and cavities; and, on the pleural surface, a number of the larger (and rarer) pendulous pear-shaped masses. The figure, he says, "represents a portion of the lung of the cow, which may be said to present a panoramic view of the seat of tuberculous matter, and the forms which it assumes in the human species, as shown in the preceding figures." Now, Carswell here speaks of the interior of the lung only, and he omits to mention, in that context, that the bovine disease has what (in his figure) the human disease wants, viz., a condition of the serous membrane which, in his own picture, is, to say the least, as prominent a feature as the condition of the lung substance, and which, in the estimation of the veterinarians of all countries, is the most obvious and not the least distinctive mark of the disease. If Carswell had figured a human lung which resembled the lung that he figures from the cow not only in its interior cavities and nodules, but also in its unique pleural outgrowths, would any one have doubted that the disease in and upon the human lung was the bovine disease, and that it was a case of tuberculosis contracted from the cow? The evidence that I have put together in Section V. is not so perfect as that evidence would have been, but it is the same in kind.[1] It is supported by the evidence as regards the lung itself given in Section VI., and I have still to show in this section how far the minute structure of the tubercles in the lymphatic glands in the recorded cases can be turned to the same account.

The minute structure of the tubercles is practically the same

[1] True pearl-nodules from a recent case are figured at the end of the paper.

in all situations, although the large flat nodules of the serous membranes show the typical characters most uniformly; and I agree with Schüppel that the tubercle, with one or more giant-cells and with a large number of epithelial-like cells, is precisely the same tubercle that occurs in the bovine species, and in its most typical form in the nodules on the serous membranes. But I would simply add that argument from histology to the other and less complex evidence of morphological identity, taking the minute structure of the nodules as evidence *pro tanto* of the disease being the specific bovine disease. I do not understand how that evidence of identity can be used to bring down the bovine disease to the level of human tuberculosis, or to some primitive type (*Urform*, as Schüppel says) common to both, and, in the face of the striking and invariable naked-eye peculiarities of the former, to rob it of its specific character. The facts seem to me rather to point to a selection of certain cases of tuberculosis in man, as being cases of the specific bovine disease; and, in going through the cases upon which Schüppel bases his argument, one might single out several which have naked-eye characters not unlike those that I would regard as characteristically bovine. It is further significant that the tubercle with giant cells and epithelial-like cells (fig. 15, Plate V.) is by no means the common tubercle of authors, and that Rindfleisch qualifies his acceptance of it by calling it the "scrofulous tubercle."

The discovery of well-defined small round tubercles (such as I have drawn in fig. 14, Plate V.) in lymphatic glands that are commonly supposed to be merely caseous, and to be themselves the centre or focus from which a tubercular infection issues—this discovery has been interpreted by Schüppel (who first made it) in the sense that the lymphatic glands are primarily affected with tuberculosis, being especially liable to it, and that, in most cases of general tuberculosis, the tubercles of the various organs are referable to the primary tuberculosis of the lymphatic glands. But Schüppel does not suppose that the primary tuberculosis of lymphatic glands is an idiopathic disease, the source of which cannot be traced farther. He quotes with approval the words of Virchow: "The primary gland-tuberculosis is primary only as tuberculosis; as an irritative process it is not primary, but the irritant always proceeds from some focus or

centre." The focus or centre is that locality from which the respective lymphatic glands receive lymph, and some inflammatory or irritative process is at work in it. Thus the primary irritation may be in the intestine, in which case the mesenteric glands become tuberculous; or it may be in the air-vesicles or bronchi, and then it is the bronchial glands which become the seat of tuberculosis.

Almost to the same effect is the opinion of Rindfleisch. Rejecting the doctrine that the essential change in lymphatic glands that become caseous is a purely hyperplastic one, and of an inflammatory kind, he says,—"I have satisfied myself, by repeated investigation, of the correctness of Schüppel's assertion that the 'scrofulous' gland is in all cases a 'genuine tuberculous' gland." The analogy that he would set up is that of tumour-infection of lymphatic glands, "only that we are not yet justified in calling the primary lesion tuberculous." The primary lesion should only be called tuberculous when, in addition to scrofulous catarrh, for example, there is also a tuberculous ulcer of the mucous membrane. A tuberculous element might be sought in the catarrh itself; but that extension of the idea should be resisted, and the anatomically specific tubercle asserted only for the second stage of the invading disease, viz., the tuberculosis of the lymphatic glands. With this reservation, Rindfleisch speaks of a primary, a secondary, and a tertiary tuberculosis. By primary tuberculosis, he means local affections of the various organs of the body, affections in which scrofulous-inflammatory and tuberculous elements may be mingled, although often only the former are present. By secondary tuberculosis, he understands the tuberculosis of lymphatic glands. Under tertiary tuberculosis, he includes the disseminated tuberculosis of various organs not primarily diseased, namely, the liver, the spleen, the lungs, the kidneys, the serous membranes, the pia mater, the marrow of bone, &c. (*loc. cit.* p. 160).

Both Schüppel and Rindfleisch regard the tuberculosis of lymphatic glands as something in the causation intermediate between the scrofulous inflammation, or catarrh, or ulceration of a certain locality, and the general tuberculosis of which the patient dies. It is only when the disease reaches the lymphatic

glands that it assumes, in many cases, the anatomically specific character of tuberculosis, and the tuberculosis so established in the lymphatic glands is the source of the infection through which the tubercles of the serous membranes, of the viscera, of the bones, &c. are produced. For the cases upon which I rest my contention of an infection from the bovine species, I find no reason to place the tuberculosis of the lymphatic glands in that causally intermediate position. In the first place, there was, as a matter of fact, no obvious inflammation or catarrh, scrofulous or other, which might be taken for the primary irritant. Secondly, the manifestations of the disease throughout the body were, in respect to its source, all on an equal footing or co-ordinate; in no organ or locality could the disease be said to be primary, while it was secondary elsewhere. The morbid products were doubtless of various ages; but one might as well argue, for a certain number of cases, that the tubercles of the serous membranes were the primary as that those of the lymphatic glands had appeared first. But, whatever the succession in time, there is not the smallest ground for asserting a causal succession; no one set of tubercles were the cause of any other set, but they were all equally due to some common cause. The obvious suggestion is a virus introduced from without, and the closest analogy is syphilis. The tuberculosis in the cases herein recorded may, if necessary, be called primary, secondary, and tertiary; those stages are, however, not subordinate but co-ordinate, just as the primary, secondary, and tertiary manifestations of syphilis are co-ordinate with respect to the initial infection. In an important article by Klebs, the occurrence of tuberculosis is attributed in a general way to a virus or an infection from without, on the analogy of syphilis. With reference to the stages of invasion, he observes:[1] "If we set out from the point of view that tuberculosis, like syphilis, owes its origin to a virus, the virus may be considered to enter the circulation in a soluble form, and then we should have numerous centres of disease established; or there may be a storing up of the virus in the lymphatic glands, followed by long periods of relatively good health, until, from these organs as centres, an

[1] Klebs, "Ueber die Entstehung der Tuberculose, und ihre Verbreitung im Körper."—Virchow's *Archiv*, xliv. (1868), p. 265.

infection of the blood or of the neighbouring tissues should arise. What Virchow has so well shown for syphilis, would thus hold good for tuberculosis." The same parallel between syphilis and tuberculosis is stated by Cohnheim in the paper already quoted.[1]

The evidence as regards the condition of the lymphatic glands would stand, therefore, as follows. They are not merely swollen by an inflammatory hyperplastic process, afterwards becoming caseous or cretaceous, but they are in the first instance occupied by small microscopic tubercles and the conglomerates of tubercles, and the tubercles become caseous or cretaceous. The tuberculosis of the lymphatic glands is not the origin of the tuberculosis elsewhere in the body, but it is a co-ordinate part of a general infection. The tuberculous or scrofulous lymphatic glands would thus lose the property that is so often assigned to them, of being the initial source or starting-point of the general tuberculosis; and, if the lymphatic glands are not that source, then there is no such primary starting-point of the disease within the body. All the manifestations of the disease within the body are on an equal footing as regards the origin of the disease, and that origin must be looked for, according to analogy, in a virus introduced from without. That the virus is the bovine tuberculous virus is made probable by the likeness in form and structure of the lymphatic glands in the cases in man, to the affected glands in the specific disease of the bovine animal, and by the fact that the disease of the lymphatic glands, both in the bovine species and in man, is associated respectively with the same structural processes in the lungs and on the serous membranes.

VIII.—The Intestinal Lesion.

The small intestine was affected in the three cases which I have placed last in the series. In two of these the intestinal lesion was recent, amounting in the one to little more than white medullary swelling of the lymphatic follicles ([illegible] mesentery [illegible]), with occasional ulceration of the follicles, and in the other to round ulcers of the ordinary tuberculous kind. But in the third

[1] [illegible] Leipzig, 1880, p. 36.

case (Case 10), the circumstances are somewhat different and much more instructive, and it is chiefly to that case that I here direct further attention.

In Case 10, the patient, a married woman aged thirty-eight, from a village near Cambridge, had been in the hospital in August 1879 with typhoid fever. I have not succeeded in finding the notes of that illness, and it is therefore impossible to say whether the symptoms were in any way different from those of ordinary typhoid fever. Several other cases of typhoid were admitted into the hospital about the same time. The disease ran its course, and she was discharged and went home; but she never was quite well from the time of leaving the hospital to her readmission in March 1880. On her return to the hospital, the symptoms were at first distension of the abdomen, pain in the left inguinal region, &c. (see notes of cases). After a few days a regular rise of several degrees in the evening temperature began to be noted, and the symptoms of an acute infection, diagnosed as tuberculosis, continued till her death on the 20th April. Both lungs were full, from apex to base, of minute translucent tubercles. In the abdomen there was recent peritonitis, the intestines being glued together. Besides the recent peritonitis, there were old adhesions in the right iliac fossa, and a small quantity of fluid was sacculated in a space formed by the adhesions. Chiefly in these adhesions, but also all over the peritoneum, there was an abundant eruption of large flat tubercles of about the size of a lentil. It at once arrested the attention that each tubercle was as if sparsely sprinkled over with minute black points, like powdered charcoal or coal dust. The lower part of the ileum contained two healed ulcers, which appeared as smooth shallow depressions, one of them half an inch in diameter, the other rather larger, amidst the villous mucous surface; a small spot of black pigmentation was visible on close examination in the extreme centre of each. The floor of the ulcer, or the cicatricial tissue, was an eighth of an inch thick, and on section was found to consist of a large number of distinct centres of new formation of the kind drawn in fig. 15, Plate VI. Only a few of the small tubercle centres were found in the submucous tissue; the great bulk of the new formation was between the serous coat and the outer muscular. Each centre of new

formation is a tubercle such as I have described several times before; it consists of large multinuclear cells, of epithelial-like cells with a single nucleus, and of numerous forms intermediate between those two. Sometimes the central substance is caseous, and then there are only two or three of the largest and most perfect giant-cells with close-set marginal nuclei, which occupy the periphery of the tubercle. Each of the large flat tubercles which lay (sometimes loosely) on the peritoneum both visceral and parietal, had precisely the same structure as the thickened floor of the healed ulcer, being composed of a number of contiguous but distinct centres of the same new formation. The pigmentation, about which there could be no doubt when the viscera were first exposed, was not apparent in the sections; nor, indeed, could it be detected with the naked eye after the parts had been preserved.

About the same time that I was examining this case, a case occurred of scirrhous cancer, secondary in a number of places, and starting apparently from the thickened base of a healed ulcer of the pylorus. There was a thickening under and around the smooth shallow depression of the mucous membrane of the pylorus, just as there was under and around the smooth shallow depression in the mucous membrane of the ileum; and the scirrhous case appeared to be a good analogy for the tubercular. As the secondary cancer nodules had emanated from the infiltration of an old ulcer of the pylorus, having precisely the same structure as that infiltration, so the large flat tubercles of the peritoneum had emanated from the ulcers of the ileum. The pigmentation of the tubercles also seemed to point to the pigmented cicatrices of the intestinal ulcers. But that analogy may be easily pushed too far. For other purposes, a primary syphilitic sore is a better analogy for the primary ulcer of the intestine; the ulcer of the ileum must be supposed to have been charged with specific properties from the first, and these to have been communicated by a virus from without. They were originally the ulcers of typhoid fever, but in their healing, or in their subsequent induration, they retained the specific infective property which afterwards manifested itself in the general tuberculosis of the peritoneum, and still later in the acute miliary (or submiliary) tuberculosis of the lungs. The large flat tubercles of the peri-

toneum are such as I take to be distinctively those of bovine tuberculosis, and I do not hesitate to conclude that the original infection in August 1879, which ran its course as typhoid fever, was an acute attack caused by the introduction of the bovine virus.

The literature of typhoid fever and of tuberculosis contains a good many cases of the same kind, which have either been accounted for by various hypotheses, or have been passed over lightly (in the systematic treatises) as troublesome anomalies. I do not refer to the well-known difficulty, in many cases, of making the diagnosis between typhoid fever and acute tuberculosis; even if all the doubtful cases which recover are admitted to be pure typhoid cases, there are a considerable number of fatal cases which run the course of typhoid and die after a longer or shorter interval of tuberculosis.[1] In the case which I have described, the patient recovered from an acute attack of typhoid, and died several months after of a disease of a tuberculous nature, which was not a new disease, but a further development of the former. For such anomalous cases of typhoid fever and tuberculosis, I regard the doctrine of the specific bovine tuberculosis communicated to man as affording a rational explanation. I proceed to mention some of the more remarkable cases in the recent literature, to which the explanation may be applied.

One of the most valuable pathological records of an extensive series of typhoid cases is that of the great Basel epidemic of 1865–67, published by Professor C. E. E. Hoffmann.[2] Among the 250 fatal cases enumerated in his conspectus of the *post-mortem* examinations, I find five put down as having miliary tuberculosis in the lungs and other organs. With reference to them, Hoffmann remarks, that the tuberculosis "is a sequel of typhoid, and always makes its appearance first after the proper typhoid process has run its course" (p. 279). His explanation of these cases is that an absorption of detritus into the juices of the body takes place from the seats of typhoid deposit. Quite distinct from these cases with "miliary tuberculosis," he found 38 cases which had small round grey nodules in the liver, and occasionally also in the kidney; these nodules had been already

[1] Curiously enough, this is still more the case in measles.

[2] C. E. E. Hoffmann, *Untersuchungen über die Pathologisch-anatomischen Veränderungen der Organe beim Abdominal-typhus.* Leipzig, 1869.

described by E. Wagner and by Friedreich, and are regarded as the specific products of typhoid in the liver. He further distinguishes from "miliary tuberculosis" a certain kind of nodules that were sometimes found on the serous coat of the ileum near the ulcers, and even on the peritoneum generally and on the pleura. It is to these cases that I wish more particularly to call attention. These nodules had already been noticed by E. Wagner,[1] who went so far as to say that they were found in all cases of typhoid, and belonged to the same class as the small grey nodules in the liver, Their occurrence is noted in only a few of Hoffmann's cases, and he gives a full record of four cases in which they were found. The nodules were of the size of hemp-seed or lentils, flat, of clear greyish colour, and sometimes of considerable density. They were seated on the peritoneal covering of the intestine in clusters corresponding in the first instance to the ulcerated patches of mucous membrane, but, if they once appear in considerable numbers on the serous coat of the intestine, "they often give occasion to more extensive inflammations, through which a multitude of such nodules may arise over great stretches of the peritoneum" (p. 68). Hoffmann's theory about them is, that they are extensions of diseased lymphatic follicles to the depth, or towards the serous surface, and he holds to that view despite the want of correspondence between their structure and the structure of the diseased follicles. One of the cases is so like the case which I described at the beginning of this section that I shall give a brief abstract of the *post-mortem* appearances.

In the apices of both *lungs* are old and firm deeply pigmented cicatrical indurations, through which are scattered a small number of sharply-bounded tough yellowish-grey nodules up to the size of lentils. Over a limited part of the upper lobe of the right lung there are several hundred flat and not sharply-bounded small grey nodules on the *pleura*, which nowhere penetrate into the interior. Similar grey nodules on a part of the pleura diaphragmatica. A quantity of yellowish-brown fluid in both pleural cavities. Similar fluid in the abdomen. The *intestines* partly glued to the parietal peritoneum, the union intimate at some places. The *peritoneal surface* of all the viscera, as well as of the abdominal walls, is sown with flat, round, somewhat diffused, nodules of the size of hemp-seed or lentils. Close above the ileo-cæcal valve, a large cicatrix in the mucous membrane, having a delicate smooth surface, the tissue near it pigmented bluish black. Further up the ileum all the Peyer's patches are marked with

[1] *Archiv der Heilkunde*, ii. (1861), p. 183.

points of bluish-green pigment and depressions corresponding. In the *liver* a large number of small grey nodules. In the *kidneys*, in the deeper parts, a small number of greyish nodules, in parts darkly pigmented, up to the size of millet seed.

This case is Hoffmann's tenth detailed case of typhoid fever. He does not even admit that the nodular eruption is tuberculosis as a sequel to typhoid, but he inclines to the opinion that these flat nodules of the serous membrane, found most commonly over the lower part of the ileum, but liable to extend all over the peritoneum and even to the pleura, belong to the specific manifestations of typhoid. But he cannot altogether agree with the opinion of E. Wagner, that they are a constant occurrence in typhoid. I do not doubt that these flat nodules of the serous membrane, which may be as large as lentils, of clear grey colour, and sometimes of firm texture, apt to be ill-defined at their margins, and, it may be, not more than half a line raised above the serous surface, are the same which I have described and figured as the more or less immature tubercles or pearls of *Perlsucht.* It is to be regretted that Hoffmann's account of their microscopic anatomy is too indeterminate to be used for the purpose of close comparison. However, it is partly on the ground of their minute structure that he refuses to admit them as miliary tubercles. They consist, he says, "of a granular ground substance traversed by delicate fibres, in which cells and nuclei are deposited, sometimes in large and sometimes in small numbers. They show therefore the same structure as the nodules in the case of Griesinger,[1] according to the investigations of Rindfleisch" (p. 61). He promises further particulars in a subsequent part of his work, but the only other reference that I can find is on p. 108, where "the grey nodules of the serosa" are attributed to an infiltration or wandering of the overgrown cells of the lymphatic follicles through the interstices of the muscular coats and into the sub-serous and serous coats.

Under the title of "Tubercular Fever," Dr John Harley has recorded a group of cases that were under his observation at the London Fever Hospital.[2] He observes: "Medical authors, it is true, have noted the occasional association of tubercle and

[1] *Infections-krankheiten*, 1864, p. 170.

[2] John Harley, "Tubercular Fever and its relation to Enteric Fever."—*St Thomas's Hospital Reports*, New Series, vol. iv. (1872), p. 63.

enteric fever, but they have all regarded it as a rare and accidental complication, or as a sequel arising from the debility caused by a prolonged attack of the enteric disease. The evidence which I lay before the reader will, I believe, be sufficient to convince him, not only that tubercle may form an actual component of enteric fever, but that fully developed enteric fever may be solely caused by the simultaneous eruption of miliary tubercle in the intestinal glands and in the lungs." In support of this position he gives thirteen cases, most of which appear to me rather to raise the old question of diagnosis as between "typhoid fever" on the one hand, and "acute tuberculosis" on the other. One of the cases was scarlet fever, with "psorentery" of the intestinal lymphatic follicles, and in the left lung, "tunnel-like ragged cavities" in the firm upper lobe, and in the lower lobe "numerous fine granules of yellow tubercle, some of which were confluent in masses the size of a pea." His tenth case, which was a typical case of typhoid, with rose-coloured spots on the abdomen, had also numerous small nodules in the lungs, which, he says, were equally typical of tuberculosis.

The most remarkable group of typhoid and tubercular cases that I have found is that of Dr W. H. Spencer.[1] Upwards of twenty boys in an industrial school in Bristol fell ill with the same sort of illness; four of them died and the rest recovered. "Epidemics of illness and enteric fever," says Dr Spencer, "had occurred in the school many times before, and the circumstances always pointed to defects in the drains as their source. At length, after one of the later outbreaks of illness, the then old brick drains (found to be very defective), were replaced by new stoneware soil-pipes. When the next outbreak occurred, it was found that some of the new stoneware pipes had cracked, and the sewage had soaked out underneath the floor of a wash-place used by the boys. After the last outbreak—the one with which we are now concerned—an inspection of the place was made by the Sanitary Authority. It was then found that some blasting operations (necessitated by alterations to the school-house) had disturbed the connections between the drain-pipes,

[1] W. H. Spencer, "On Fever as a connecting link between Scrofula and Tuberculosis."—*Bristol Royal Infirmary Reports*, 1878-79.

and that the sewage had again soaked out under the floor of the wash-place. I am told by the Medical Officer of Health that the defects then again, for the third time, discovered in the drains, allowed a free current of sewer-gas to blow into the building; that, in fact, the interior of the building was brought into direct and open communication with a very large portion of the sewer-system of Bristol. The Medical Officer of Health came to the conclusion that this last outbreak of illness in the school was one of enteric fever; and, under all the circumstances, his only wonder was that any of the inmates of the school escaped." The symptoms noted in all the cases were "malaise, headache, foul tongue, and gastric irritation; in some cases tenderness in the right flank and epigastrium, and in some cases diarrhœa; in all the cases fever. There were some twenty or twenty-five cases in all. Most of the boys got well under treatment. Four boys were more ill than the rest, and because of the severity of these cases, and because they were considered to be bad cases of enteric fever, the boys were sent to the Bristol Infirmary. In these four cases sent to the Infirmary the symptoms began in the same way as in the other slighter cases, and were similar, but the temperature from the first was higher and all the symptoms were more severe." The age of the boys was from twelve to fourteen; death occurred from three to four weeks after the commencement of the illness. Now, what was the disease found *post mortem?*

Case I. had tubercles of the *arachnoid;* tubercles throughout the left *lung*; a patch of tubercles on the *diaphragmatic pleura* of the left side, tubercles on the *surface of the liver*, *surface of the spleen*, and surface of the right *kidney* (under the capsule); a caseous *bronchial gland;* and ulcerated *Peyer's patches.*

Case II. had tubercles of the *arachnoid;* both *lungs* full of tubercles; tubercles on the *surface of the liver;* tubercles in the *spleen* and *kidneys;* caseous *bronchial glands;* ulcerated *Peyer's patches;* tubercles in the *duodenum.*

Case III. had tubercles of the *arachnoid;* tubercles throughout the right *lung* and caseous mass at the apex; tubercles over the whole right *pleura*, and recent adhesions; caseous *bronchial glands* of the right side; ulcerated *Peyer's patches.*

Case IV. had tubercles of the *arachnoid;* tubercles (not numerous) throughout both *lungs;* tubercles all over both *pleuræ; peritoneum of diaphragm, liver, spleen, intestine, and abdominal wall studded with*

centre." The focus or centre is that locality from which the respective lymphatic glands receive lymph, and some inflammatory or irritative process is at work in it. Thus the primary irritation may be in the intestine, in which case the mesenteric glands become tuberculous; or it may be in the air-vesicles or bronchi, and then it is the bronchial glands which become the seat of tuberculosis.

Almost to the same effect is the opinion of Rindfleisch. Rejecting the doctrine that the essential change in lymphatic glands that become caseous is a purely hyperplastic one, and of an inflammatory kind, he says,—"I have satisfied myself, by repeated investigation, of the correctness of Schüppel's assertion that the 'scrofulous' gland is in all cases a 'genuine tuberculous' gland." The analogy that he would set up is that of tumour-infection of lymphatic glands, "only that we are not yet justified in calling the primary lesion tuberculous." The primary lesion should only be called tuberculous when, in addition to scrofulous catarrh, for example, there is also a tuberculous ulcer of the mucous membrane. A tuberculous element might be sought in the catarrh itself; but that extension of the idea should be resisted, and the anatomically specific tubercle asserted only for the second stage of the invading disease, viz., the tuberculosis of the lymphatic glands. With this reservation, Rindfleisch speaks of a primary, a secondary, and a tertiary tuberculosis. By primary tuberculosis, he means local affections of the various organs of the body, affections in which scrofulous-inflammatory and tuberculous elements may be mingled, although often only the former are present. By secondary tuberculosis, he understands the tuberculosis of lymphatic glands. Under tertiary tuberculosis, he includes the disseminated tuberculosis of various organs not primarily diseased, namely, the liver, the spleen, the lungs, the kidneys, the serous membranes, the pia mater, the marrow of bone, &c. (*loc. cit.* p. 160).

Both Schüppel and Rindfleisch regard the tuberculosis of lymphatic glands as something in the causation intermediate between the scrofulous inflammation, or catarrh, or ulceration of a certain locality, and the general tuberculosis of which the patient dies. It is only when the disease reaches the lymphatic

glands that it assumes, in many cases, the anatomically specific character of tuberculosis, and the tuberculosis so established in the lymphatic glands is the source of the infection through which the tubercles of the serous membranes, of the viscera, of the bones, &c. are produced. For the cases upon which I rest my contention of an infection from the bovine species, I find no reason to place the tuberculosis of the lymphatic glands in that causally intermediate position. In the first place, there was, as a matter of fact, no obvious inflammation or catarrh, scrofulous or other, which might be taken for the primary irritant. Secondly, the manifestations of the disease throughout the body were, in respect to its source, all on an equal footing or co-ordinate; in no organ or locality could the disease be said to be primary, while it was secondary elsewhere. The morbid products were doubtless of various ages; but one might as well argue, for a certain number of cases, that the tubercles of the serous membranes were the primary as that those of the lymphatic glands had appeared first. But, whatever the succession in time, there is not the smallest ground for asserting a causal succession; no one set of tubercles were the cause of any other set, but they were all equally due to some common cause. The obvious suggestion is a virus introduced from without, and the closest analogy is syphilis. The tuberculosis in the cases herein recorded may, if necessary, be called primary, secondary, and tertiary; those stages are, however, not subordinate but co-ordinate, just as the primary, secondary, and tertiary manifestations of syphilis are co-ordinate with respect to the initial infection. In an important article by Klebs, the occurrence of tuberculosis is attributed in a general way to a virus or an infection from without, on the analogy of syphilis. With reference to the stages of invasion, he observes:[1] "If we set out from the point of view that tuberculosis, like syphilis, owes its origin to a virus, the virus may be considered to enter the circulation in a soluble form, and then we should have numerous centres of disease established; or there may be a storing up of the virus in the lymphatic glands, followed by long periods of relatively good health, until, from these organs as centres, an

[1] Klebs, "Ueber die Entstehung der Tuberculose, und ihre Verbreitung im Körper."—Virchow's *Archiv*, xliv. (1868), p. 265.

infection of the blood or of the neighbouring tissues should arise. What Virchow has so well shown for syphilis, would thus hold good for tuberculosis." The same parallel between syphilis and tuberculosis is stated by Cohnheim in the paper already quoted.[1]

The evidence as regards the condition of the lymphatic glands would stand, therefore, as follows. They are not merely swollen by an inflammatory hyperplastic process, afterwards becoming caseous or cretaceous, but they are in the first instance occupied by small microscopic tubercles and the conglomerates of tubercles, and the tubercles become caseous or cretaceous. The tuberculosis of the lymphatic glands is not the origin of the tuberculosis elsewhere in the body, but it is a co-ordinate part of a general infection. The tuberculous or scrofulous lymphatic glands would thus lose the property that is so often assigned to them, of being the initial source or starting-point of the general tuberculosis; and, if the lymphatic glands are not that source, then there is no such primary starting-point of the disease within the body. All the manifestations of the disease within the body are on an equal footing as regards the origin of the disease, and that origin must be looked for, according to analogy, in a virus introduced from without. That the virus is the bovine tuberculous virus is made probable by the likeness in form and structure of the lymphatic glands in the cases in man, to the affected glands in the specific disease of the bovine animal, and by the fact that the disease of the lymphatic glands, both in the bovine species and in man, is associated respectively with the same structural processes in the lungs and on the serous membranes.

VIII.—The Intestinal Lesion.

The small intestine was affected in the three cases which I have placed last in the series. In two of these the intestinal lesion was recent, amounting in the one to little more than white medullary swelling of the lymphatic follicles ("psorentery"), with occasional ulceration of the follicles, and in the other to round ulcers of the ordinary tuberculous kind. But in the third

[1] Cohnheim, *Die Tuberculose vom Standpunkte der Infectionslehre*. Leipzig, 1880, p. 36.

case (Case 10), the circumstances are somewhat different and much more instructive, and it is chiefly to that case that I here direct further attention.

In Case 10, the patient, a married woman aged thirty-eight, from a village near Cambridge, had been in the hospital in August 1879 with typhoid fever. I have not succeeded in finding the notes of that illness, and it is therefore impossible to say whether the symptoms were in any way different from those of ordinary typhoid fever. Several other cases of typhoid were admitted into the hospital about the same time. The disease ran its course, and she was discharged and went home; but she never was quite well from the time of leaving the hospital to her readmission in March 1880. On her return to the hospital, the symptoms were at first distension of the abdomen, pain in the left inguinal region, &c. (see notes of cases). After a few days a regular rise of several degrees in the evening temperature began to be noted, and the symptoms of an acute infection, diagnosed as tuberculosis, continued till her death on the 20th April. Both lungs were full, from apex to base, of minute translucent tubercles. In the abdomen there was recent peritonitis, the intestines being glued together. Besides the recent peritonitis, there were old adhesions in the right iliac fossa, and a small quantity of fluid was sacculated in a space formed by the adhesions. Chiefly in these adhesions, but also all over the peritoneum, there was an abundant eruption of large flat tubercles of about the size of a lentil. It at once arrested the attention that each tubercle was as if sparsely sprinkled over with minute black points, like powdered charcoal or coal dust. The lower part of the ileum contained two healed ulcers, which appeared as smooth shallow depressions, one of them half an inch in diameter, the other rather larger, amidst the villous mucous surface; a small spot of black pigmentation was visible on close examination in the extreme centre of each. The floor of the ulcer, or the cicatricial tissue, was an eighth of an inch thick, and on section was found to consist of a large number of distinct centres of new formation of the kind drawn in fig. 15, Plate VI. Only a few of the small tubercle centres were found in the submucous tissue; the great bulk of the new formation was between the serous coat and the outer muscular. Each centre of new

on the periphery, and with a clear central area of finely granular protoplasm, figure in the intestinal lesion as they do in other situations, and in the same association with epithelial-like cells.

IX.—Summary.

Perlsucht, or the pearl-disease of the bovine species, has a sufficient number of distinctive characters to separate it from all other diseases. The formations on the pleura and peritoneum are the main feature of the disease, and they are said also to be the earliest indications of its presence in the body of the animal. These formations of the serous membranes begin as soft vascular, villous-like outgrowths, which in course of time become consolidated, or develop nodules in their substance; and the nodules so formed are the pearls of the disease. They are often suspended as if on threads, being joined together by rounded cord-like processes proceeding from the poles of the nodules; they may become more or less confluent, and the confluent masses of nodules may grow to a great size, in which case they hang from the serous membrane by a stalk. Most commonly the pearl-nodules are about the size of lentils, and they may be even miliary and submiliary. The round or oval flattened nodules, of the size of lentils, are often found on the pleura or peritoneum in dense masses resembling the compact convex leaves of duckweed on the surface of a pool; hence the name of *Meerlinsigkeit*, by which the disease is known in the earlier German veterinary writings. While these tumour-like formations of the serous membranes have always ranked as the leading feature of the disease, it is generally admitted that the implication of the lymphatic glands is only second in importance as a constant character, and the "pearl-disease" has also been called the "gland-disease." The bronchial and mediastinal glands, and the mesenteric and retroperitoneal are liable to be affected. They sometimes grow to an enormous size, from the formation of a number of nodules in their interior, and, like the pearl-nodules, they are liable to cretaceous and cheesy necrosis. According to the best veterinary authorities, a cow with pearl-disease hardly ever escapes without disease of the lungs. The disease in the lungs takes the form of isolated nodules, mostly situated near the surface, which are

made up of the confluence of a number of smaller nodules. These masses are sometimes found as if encysted or encapsuled, and when they begin to soften in the interior, the encapsulation becomes more marked. Closed vomicæ with thick smooth walls are another feature of the disease in the lungs; they arise from the softening of the encapsuled nodules, but they often communicate with the eroded end of a bronchus, and that fact has given rise to the mistaken opinion that the smooth-walled vomicæ of the lung in pearl-disease are portions of dilated bronchi. The lungs may contain, also, nodules much smaller, down to the size of a mere visible point. In a certain proportion of animals the disease extends beyond the serous membranes, the lymphatic glands, and the lungs, and attacks the intestine, the liver, the joints, the bones (bodies of vertebræ), the genito-urinary organs, and the udder. The new formation has, generally speaking, the same structure in all situations. That which at once arrests the attention in its microscopic anatomy, is the abundance of giant-cells; the most perfect of these elements have an enormous number of small round or oblong nuclei grouped along the sides, leaving a central space of granular protoplasm. The next most distinctive elements in the nodules are epithelial-like cells, which may have one or more nuclei, passing by transitions into the class of giant-cells. Those characters are best seen in the lentil-like nodules of the serous membranes. The new formations are liable to caseous and cretaceous necrosis; but they have a considerable power of growth, and they are often not ill-provided with blood-vessels, at least in their outer layers. Owing to their considerable degree of vascularity, the nodules of the pearl-disease have been compared to sarcomatous growths. There is, on the whole, much that is distinctive of this disease, and there is a certain unity in its various manifestations throughout the body of the animal. It may be said that the pearl-disease is to the bovine species what glanders is to the equine.

The pearl-disease of bovine animals has been communicated to other animals by experiment. Prolonged feeding with the milk of a tuberculous cow, or with the actual pearl-nodules, has sufficed to set up a corresponding disease in the calf, lamb, goat, pig, and rabbit. The induced disease differs from the

original disease of the cow in the important respect that the former is a somewhat acute infective process, whereas the latter, generally inherited, is of slow development. Corresponding to this difference in the intensity of the process, the morbid products in the cases of induced pearl-disease are not quite the same as in the indigenous bovine disease. They are not quite the same, but the identities of form and structure are sufficiently striking. Thus, although the serous membranes are, in the infected animals, seldom or never covered by pendulous nodules or conglomerates of nodules, they will be found on close examination to show traces of those soft vascular villous-like outgrowths which are known to be the early stage of the nodular formations. To use the convenient expression of Gerlach, they show "the beginnings of Perlsucht." The experiments which Orth made with rabbits did not result in producing a disease identical in every point with that of the cows from which the infecting material was taken; but the resemblance was sufficiently close to lead Orth to speak of the disease induced in the rabbit as "Kaninchen-Perlsucht." In particular, the microscopic structure is the same, and, on the crucial point of the vascularity of the new growth, Gerlach has noted a certain amount of evidence of identity. The implication of the lymphatic glands, also, is practically the same in the experiment-animals as in the cow. It is not difficult to suggest the reason why the induced disease as a whole is somewhat unlike the parent disease. In the disease communicated by the feeding experiments, the morbid process in the lungs seems to take precedence, owing to the mode of entrance of the virus, over that on the serous membranes. The latter is no longer the chief feature of the disease, but what there is of it is characteristic enough.

There is little doubt that the pearl-disease, modified only in the relative development of the process in the various organs, has been communicated to animals by experiment. There is evidence, also, that it has been communicated to animals by accident. Has it ever been communicated by accident to man? There is no lack of reasonable presumption that it has. The analogous disease of the horse is now and then communicated to man; but we are brought into much closer contact with the bovine species than with the equine. Besides bread, there is

hardly a more universal article of diet than cow's milk. There are many more tuberculous cows than there are glandered horses, and it would take a good deal to re-assure us that we do not sometimes partake of their tainted milk. Such arguments are plausible enough, but they do not prove that bovine tuberculosis ever has been communicated to man. I do not see how such communication ever can be proved, except by the evidence that the form and structure of morbid products in the human body are the same as those of the bovine pearl-disease. The preceding pages are my contribution, such as it is, towards that not very easy proof. The obvious objection to the cases that I here record is, naturally, that we have known such cases for a long time, and have not called them bovine tuberculosis. But, if there is anything in the notion that bovine tuberculosis is communicable to man, the disease must be of long standing among human diseases, although it has never got into the nosology. Under what names, then, have we been speaking of bovine tuberculosis in the past? First and foremost there are the sudden and unaccountable onsets of tuberculosis both in children and in adults. There is a growing conviction that such cases are due to the introduction of a specific virus into the body, and it is a question of morphological evidence whether, in any particular case, the morbid products are those that would be due to the specific bovine virus. It is the evidence of identity in form and structure that I have dwelt so much upon in this paper; and I would claim no case of tuberculosis in man as a case of communicated bovine tuberculosis, unless I found on the serous membranes (especially on the sharp margins of the lungs, and on the under surface of the diaphragm), or in the lymphatic glands, or in the lungs, or in all these together, and occasionally in other parts and organs, those evidences both of form and minute structure which are distinctive of the bovine disease as it exists primarily and specifically in the cow.[1]

The cases of tubercular peritonitis, tubercular pericarditis, and tubercular pleurisy, which every one must feel to occupy at

[1] Klebs (Virchow's *Archiv*, xlix. (1870), p. 291) observes that "the new formations of Perlsucht represent only a special development of tubercle, which corresponds in all points with the so-called *fibrous tubercle* of man."

present a very unsatisfactory position in pathological theory, appear to me to form one of the most likely groups of cases among which to look for instances of infection from the pearl-disease.[1] There is even reason to think that still more characteristic instances of the serous-membrane new formations have occurred in the human subject, in the form of large pendulous nodules, and under the name of cancers.

There is much likelihood that some at least of the many things called scrofulous are manifestations in the human body of the specific bovine virus. No part of the experimental inquiry now going on under Virchow's direction at Berlin will be watched with greater interest than that which relates to the significance of the scrofula found in pigs which have been fed with substances from tuberculous cows. The result of those experiments will doubtless afford valuable indications as to the presence or absence of the same virus in particular cases of scrofulosis of the lymphatic glands, of the joints, of the genito-urinary organs, or of the brain, in the human subject.

Lastly, I have given, in Section VIII., certain reasons for thinking that bovine tuberculosis has sometimes appeared in man in the form of typhoid fever; and I have put the question whether the fatal cases in those epidemics of typhoid fever that are due to poisoned milk, have nothing in their morbid anatomy to suggest the pearl-disease of the cow. Certain it is that cases of typhoid fever, with flat nodules of the peritoneum, do sometimes occur.

The difficulty with typhoid fever, as with tuberculosis, which most naturally suggests itself, is that the disease is one and indivisible, and that it is exceedingly improbable that a certain proportion of cases, mixed up with and not clinically distinguishable from the others, should be cases of bovine tuberculosis. Typhoid fever is, without doubt, propagated in the larger number of cases from pre-existing cases of the same disease in the human subject; but is it altogether inconceivable that an acute infective process, not distinguishable from typhoid fever, should be set up in isolated cases by the bovine tuberculous virus? In like manner, if tuberculosis in man is an infective

[1] See Garlick, "Remarks on the Peritoneal Tuberculosis of Children," *Lancet*, 25th Dec. 1880.

process, and in many cases propagated (as able pathologists believe) by infection within the human species, is it not conceivable that it may, in some other cases, be imported direct from the cow?

In the section on the lymphatic glands (Section VII.), I have contended that the best analogy for the bovine tuberculous virus is, in some respects, the virus of syphilis; and I quoted the opinion of Klebs that, as in syphilis, so in infective tuberculosis, the stages of invasion may succeed each other rapidly, or may be separated by long intervals. Those cases in which the lymphatic glands are most affected would be the most chronic, and those cases in which the virus reaches the pulmonary circulation most directly would be the most acute. The virus would probably enter the body in the great majority of cases by way of the digestive tract; but it must often be absorbed from an intact mucous membrane. When ulcers of the intestine do occur, they are not always the primary seat of the disease in the body.

Like other kinds of virus or animal poison, the virus of the pearl-disease must be considered to vary much in intensity, and to be uncertain in its action. The variations in its intensity, and the uncertainty of its action, would depend partly on the inherent qualities of the particular virulent substance, and partly on the predisposition of the individual who is subject to its action. Its effects are probably slight in many cases; and even if the onset is attended with fever and the symptoms of an acute infection, the attack may be recovered from. According to the observations of Orth on rabbits, it required the administration of considerable quantities of the tuberculous substance, and a period of not less than three months, before the disease could be communicated in a well-marked form (p. 179).

The doctrine of a tuberculous virus was stated by Klebs in 1868, and has been advocated by him, as well as by Cohnheim, in recent writings.[1] In its latest form, this doctrine asserts the existence of a specific minute organism to whose agency the infection is due. The minute organism is called by Klebs *Monas tuberculosum*. The method of proof which I have followed in this work makes it impossible that the infective agency of a minute organism should in any way come into my view of the

[1] Klebs, *Prager Medicin. Wochenschrift*, 1877, No. 72.

communication of bovine tuberculosis to man. I have rested the whole case upon certain minute identities of form and structure in the infected body, due to the mimicry of infection. Among other points, there were the leaf-like and cord-like outgrowths of the pleura and peritoneum, these being the early stages of the lentil-like or pearl-like nodules and their connecting threads; the lymphatic glands, with distinct nodular formations in their substance; the lungs, with smooth-walled closed vomicæ or with encapsuled nodules. In the new formations generally there was a particular pattern of microscopic structure, in which giant-cells and epithelial-like cells figure largely, and there was

Two groups of pearl-nodules from under surface of diaphragm, in a man aged 40, who died of rapid phthisis (Addenbrooke's Hospital, 15th Nov. 1880).

a relatively high degree of vascularity. In all these points the disease in man is a mimicry of the parent disease in the bovine animal. That mimicry is not only in single features, but it is of the whole disease. It is possible to conceive of the juices and particles of the primarily diseased body acquiring a kind of spermatic virtue, which gave them the power to communicate the specific disease as a whole and in all its several manifestations to another body in which they should happen to lodge. But it is hardly possible to think of a neutral living organism being charged with the power of conveying so complex details of form and structure from one body to another.

CASE OF MEDULLAR[illegible] OF THE BRAIN.

By WILLIAM OSLER, [illegible] Lond., *Professor of the Institutes of Medicine, M'Gill University, Montreal.* (PLATE XVIII.)

JOSEPHINE N——, age 16, admitted to the Montreal General Hospital, under Dr Ross, 2nd Dec. 1879.

History.—Has been blind since third year; loss of sight is said to have followed scarlatina. Had measles at eighth year, and shortly after an account is given of what appears to have been a temporary hemiplegic attack, lasting only one day. It is difficult to obtain satisfactory details, as she is in the care of people who know but little of her early history. In July 1878, she began to have headaches, which persisted through the months of August and September, and there appear to have been attacks of spasms of the muscles of one side, lasting for a quarter of an hour each day. She was better in October, and on the 11th of November returned to her studies at the Blind Asylum. She remained well until about two weeks ago, when the headaches returned, and on the 29th of November she had a spasm during the night. Since then the headaches have come on every day. There is no history of syphilis or of any injury.

Present Condition.—Patient is a dark-complexioned, well-nourished French Canadian girl, bright and intelligent, answers questions freely, speaks English, and has made good progress in her musical education at the Asylum for the Blind. The head is not unusually large, decidedly not hydrocephalic, forehead not prominent, the left side is fuller behind than the right. There is complete atrophy of the optic nerves. Has had no vomiting, no fever. Walks well, and has complete command of all the limbs. When first brought to the hospital the gait was irregular and unsteady, and the possibility of cerebellar disease was suggested by the admitting physician. There is nothing of the kind now. Abdominal and thoracic organs healthy. Patient was put upon bromide of potassium, grs. v. every five hours. The headaches were relieved, and she left the hospital

on the 9th, no "spasms" having occurred during her stay. On the 15th she was readmitted. Pains in the head had recurred after leaving the hospital, and on the 10th the head became drawn down by contraction of the muscles of the right side of the neck, and they are now (16th) in a state of firm contraction. There is much pain in the head, chiefly occipital, and there are also pains in the neck and chest. At 10.30 p.m. a hypodermic injection of morphia (gr. ¼) was given; at 11 o'clock she was asleep, at 12.30 a.m. was awake, and said she felt easy. At 1.30 a.m. she was found dead. The mode of death was not observed.

Autopsy.—Body well nourished; nothing of note in external inspection. Signs of puberty marked.

Calvaria, at line of section, of average thickness, slightly expanded in parietal regions; left half is decidedly larger than the right. *Dura mater* is so firmly adherent that the brain had to be removed with the skull-cap; membrane is thin; sinuses contain small quantity of blood. When the brain was turned out of the skull a large quantity of clear fluid escaped; the organ is remarkably soft and fluctuating, and when laid on the table the hemispheres collapse as the fluid escapes. The vessels of the pia mater contain blood; arachnoid not opaque. Vessels and membranes at the base look healthy. Convolutions are flattened, and the sulci are almost obliterated. On separating the hemispheres the corpus callosum looks thin, particularly in its posterior half. Projecting from behind it is a large clear cyst, which lies upon the upper surface of the cerebellum. The lateral ventricles were then exposed and found to be enormously distended. So much fluid escaped in the manipulation of the organ that the total quantity could not be estimated, but it must have amounted to nearly a pint. The left ventricle is the largest; the distension is tolerably uniform, but does not affect the anterior cornua so much as the others; the hippocampi are fully exposed. The lining membrane is clear, nowhere granular, and numerous vessels course beneath it. The brain substance of the hemispheres is much reduced. Over the central part, in the region of the parietal convolutions, it is not more than 5 or 6 mm. in thickness. The grey matter is everywhere thicker than the white layer; in the neighbourhood of the fissure of

Rolando the grey layer measured 3 mm., the white only 2 mm. Over the anterior and posterior parts of the distended cavities the brain substance is not so expanded; this is particularly the case with the frontal lobes, the distance from the anterior cornua to the pia mater is here nearly normal. The structures forming the floor of the lateral ventricles are greatly flattened, the corpora striata and thalami appear superficially of large size, especially on the left side. The fornix is very thin; the velum interpositum is closely adherent on the left side to the tumour to be described, and its vessels are full. The choroid plexuses look natural, though flattened. The clear cyst, projecting beyond the corpus callosum, is directly continuous with the ventricles. It has flattened the upper surface of the cerebellum and the corpora quadrigemina, the nates and testes being scarcely distinguishable. The membrane enclosing the cyst above is thin and clear.

Lying upon the left thalamus opticus is a brownish yellow elevated mass, about 3 cm. in length, 2·5 cm. in breadth, extending over the choroid plexus towards the descending cornu. At the inner side it is attached to the fornix, beneath which it extends, and is continuous with a rounded greyish-white body in the third ventricle. The part on the thalamus is firm, and several yellowish-brown bands pass from it over the corpus striatum. The choroid plexus lies beneath its hinder part, and is closely adherent. On the surface are several small calcareous particles. The growth in the third ventricle, when fully exposed, is found to project from the upper part of the side of the thalamus, and to be continuous with the mass in the lateral ventricle. It occupies the anterior half of the third ventricle, touching the thalamus of the other side, and in front is closely united to the pillars of the fornix. It has a greyish colour, is soft, surface smooth, and altogether it has the appearance of a young, rapidly-growing neoplasm. On making an incision through the anterior part of the tumour, it is found to extend to the depth of about 8 mm., has a greyish brown translucent aspect, and though it appears to grow directly from the thalamus, yet the difference in the two is evident. At this section also the growth in the third ventricle is cut, and is seen to be lighter in colour, and is of softer consistence than the main mass. The

tumour gets thinner as it passes backward, but maintains the same structure throughout. The substance of the thalamus looks normal, and is the same on both sides. Corpora striata and lenticular ganglia much flattened, normal-looking on section. The aqueduct of Sylvius is almost closed. Corpora quadrigemina, crura, pons, and medulla present when sliced a normal appearance. Cerebellum presents a flattened depression on its upper surface; substance is healthy.

Optic nerves and tracts firm, small, and atrophic.

The examination of the thoracic and abdominal organs revealed nothing of note in this connection.

Histological Examination.

Tumour on Thalamus opticus.—The matrix or ground substance is granular in character, resembling closely that of the cerebral grey matter (fig. 1). The granules are small and dark, and in places little spherules are mingled with them. Towards the surface, where the mass is firm, there are numerous fine interlacing fibrils passing through the matrix, and they are also abundant at the inner part of the mass, where it is continuous with the growth in the third ventricle. In the matrix are—

(1.) Small corpuscles, about the size of white blood corpuscles, of various shapes, some round or ovoid (figs. 2 and 3), with large vesicular nuclei; others stellate, with three or more fine processes (figs. 4 and 5).

(2.) Large cells, looking like ganglion cells (figs. 1, 6 and 7), having processes, darkly granular protoplasm and large muclei. They are elongated or flattened, with one, two or more processes, which can sometimes be traced for a considerable distance in the matrix. The muclei are large, usually single, and about some of them an aggregation of brown granules was observed. They are tolerably abundant throughout the substance. The measurement of these cells ranges from ·0300 to ·0550 mm. In addition, there are rounded granular cells without processes, which are occasionally seen in groups of six or eight.

(3.) Medullated nerve fibres (fig. 8); seen best in teased preparations taken from the central and inner portions of the

mass. They have a distinctly double contour line, the inner one often irregular, and in many fibres the coagulation of the medulla could be seen, while small rounded masses of it (myelin drops) occur here and there in the field. These nerve fibres were abundant in some bits, scanty in others.

(4.) Delicate translucent fibres, with peculiar bead-like swellings at different parts (fig. 9). They are tolerably uniform in size, and the swelling occurs irregularly in their course; frequently a fibre appears to end or begin in one. The substance of the enlargement is uniform with, and continuous into, that of the fibre. In places these are numerous, particularly towards the mass in the third ventricle.

(5) Giant cells, few in number, with 8–12 nuclei, and dark granular protoplasm.

Tumour in Third Ventricle.—Teased bits show a structure differing in many respects from the one above described. It is composed of—

(1.) Large spindle-shaped cells, which, with their greatly elongated processes, make up the chief part of the mass. They look like enormous connective-tissue corpuscles (fig. 10), and vary in size and general appearance. Some are very slender, and taper gradually: others are more distinctly spindle-shaped, and the processes can be traced for a considerable distance before assuming the delicacy of a fibril; in others, again, the processes are broad and flat, not tapering, but keep the same diameter, or even increase a little in width. In several cells such a broad process was observed to leave one end, while a fine delicate one was given off from the opposite side (fig. 11). So elongated and attenuated do these processes become, that a small teased bit looks as if it were composed almost entirely of somewhat coarse areolar fibres, among which corpuscles were scattered; but a careful examination shows that the fibres are only the prolonged extensions of large cells. Isolated cells were measured as much as ·4130 of a millimetre in length. The majority of the cells present elongated nuclei occupying a large portion of the centre of the cells; in some it is distinctly vesicular in character; in others, granular, with indefinite outlines. The protoplasm of the cell body is either homogeneous or very finely granular, and a

similar appearance is presented by the processes. The fibrils measure from ·00166 to ·0025 m. in diameter.

(2.) Scattered amongst the preceding are a few cells like them in general outline and in the prolongation into fibres, but differing in the extraordinary translucency of the protoplasm and the absence of a nucleus (fig. 12). The term "vitreous" best expresses the appearance of these structures. Some of them were quite as long as the ordinary forms; one was observed which extended through two and a half fields of the No. 9 in. (Hartnack). In several a few fine granules were noticed about the broader parts, but as a rule the body and processes maintained a uniform and remarkable translucency.

(3.) Large granular corpuscles, interspersed among the fibre cells, and of very varied sizes and shapes; some are flask-shaped, with a single clear process (fig. 14); others are large, broad, flattened, bipolar cells (fig. 13). The nuclei are large, sometimes granular; in some no nucleus could be seen. The protoplasm is in most granular, in a few clear. The processes are flattened, not long, and resemble strongly the broader variety of process seen in the cells described under (1). These cells often occurred in groups, accompanied by smaller rounded ones, very granular, with distinct nuclei, but without processes.

Remarks.—The so called medullary or ganglionic neuroma is perhaps the most uncommon form of tumour met with. So far as I can ascertain, no case has been reported in the British journals. The literature of the subject is fully given in Virchow's work on Tumours.[1] In most of the instances there referred to the new growth was in the lateral ventricles, and, as in the present case, in connection with hydrocephalus. In a few the growth was situated in the white substance of the centrum ovale.

From the description above given, there can be no doubt that the tumour on the left thalamus is composed of a tissue similar to brain matter, and from the situation and the continuity with this ganglion, it may probably (with others of the same kind) be regarded, as Laucereaux suggests, as an *heterotopy* of the grey substance rather than a true neoplasm. Indeed, this writer[2]

[1] French edition, vol. iii. p. 457.

[2] *Traité D'Anatomie Pathologique*, tome i. 467.

holds that if all the cases which can be regarded as malformation of the brain substance be ruled out, the existence of a true neuroma of the brain is doubtful. The histological interest of this case centres in the growth which occupies the anterior half of the third ventricle, and which is continuous with, though differing from, the tumour on the thalamus. What is the nature of the enormous spindle cells of which it is in great part composed? Do they correspond to connective tissue corpuscles, or are they modified nerve cells with greatly extended fibrillar processes? The only form of tumour which has such enormous fibre cells is the large spindle-celled sarcoma; but such a growth has never been found in the brain, and, moreover, the processes of its cells do not, I think, ever become prolonged into such delicate fibrils as in this case,—at any rate, with retention of the character of the cell itself. The only instance I can find of a brain tumour containing somewhat similar elements is one referred to by Lancereaux,[1] occurring in the white substance of the left hemisphere. It was composed of large cells, many of them fusiform, with ribbon-like processes. In the figure which he gives, certain of the cells bear a resemblance to the ones above described, and he regards them as probably nervous in character. I am inclined to take the same view in the present instance. The majority of the cells are greatly elongated, with flattened or attenuated processes, and look like large connective tissue corpuscles; among them, however, are corpuscles which resemble ganglion cells, and possess also similar ribbon-like processes (figs. 13, 14). I believe that a careful study of the growth warrants the supposition that the elongated fibre cells are transformations of structures closely resembling nerve elements. The peculiar fibre cells above described, with extraordinarily translucent protoplasm and no discernible nuclei, are structures which, though unlike nerve fibres in general appearance, remind one strongly of the gelatinous fibres of Remak. On the view that these elongated cells are transformed nerve corpuscles, what are the fibre-like extensions in connection with them which cannot be distinguished microscopically from areolar fibres? Though a somewhat heterodox view, it appears probable, from the researches

[1] *Loc. cit.*

of Stricker and Unger,[1] that nerve cells may give off processes which pass into connective-tissue fibres, and these authors regard the protoplasmic processes (with their fibrillar extensions) of the cells of the central nervous system as of this nature. If such is the case, we can look upon the fibrillar extensions of the cells in this instance as constituting in reality, what they so much resemble, connective-tissue fibres, or we can suppose a transformation or degeneration of the nerve cells into fibre cells.

Doubtless, as Virchow supposes, the malformation forming the tumour in the thalamus, was congenital. The early blindness at the third year, and the hemiplegic attack at the eighth, favour this supposition.

The hydrocephalus can scarcely have begun in early childhood before the closing of the sutures, else the head would have become enlarged. It was only in July 1878 that she began to suffer from headaches and to have unilateral "spasms," and it may be that the distension of the ventricles dates from about this time. The tumour in the third ventricle looks recent, and it may have been its growth and the increasing induration about the mass on the thalamus (to which the velum interpositum was firmly adherent) which caused pressure on the venæ Galeni sufficient to induce the ventricular dropsy.

Clinically also the case is of interest, chiefly from the negative character of the symptoms. Headache was the only prominent one during her first stay in hospital. On the second admission the muscles of the right side of the neck were strongly contracted, and the pain in the head was severe. The cause of the sudden death could not be ascertained. The mental condition of the girl was remarkable, considering the degree of hydrocephalus and the extent of atrophy of brain substance. In the majority of such cases there has been more or less impairment of the mental powers, but this girl appears to have had quite the ordinary intelligence, and for her station, and considering also her blindness, was well educated.

[1] *Vorlesungen über allgemeine und experimentelle Pathologie*, von Dr S. Stricker, III. Abtheilung, II. Lief., 1880.

EXPLANATION OF PLATE XVIII.

1-9. From mass on left thalamus.

10–14. From tumour in 3d ventricle.

(1), General appearance of the matrix, with a ganglion cell imbedded in it; (2, 3, 4, and 5), small cells, some looking like corpuscles of the neuroglia; (6 and 7), large ganglion cells; (8), double contoured nerve fibre; (9), fibres, probably nervous, with curious bead-like swellings; (10 and 11), elongated fibre-cells from mass in 3d ventricle; (12), very translucent fibre without nucleus; (13 and 14), cells resembling nerve corpuscles, with ribbon-like processes.

DISSECTION OF THE GENITO-URINARY ORGANS IN A CASE OF FISSURE OF THE ABDOMINAL WALLS.

By Alban Doran, F.R.C.S. (Plate XIX.)

In September 1880, Mr Ritchie Norton, of Tottenham, presented to the Museum of the Royal College of Surgeons a monstrous fœtus. The abdominal walls were entirely deficient except immediately above the pubis, the viscera hanging freely from the body. On closer inspection, I found that the genito-urinary organs were imperfectly developed and malformed to a degree rare, even in cases of complete extroversion of the abdominal viscera. The nature of the series of malformations which I detected in those organs will be presently described.

The mother was a healthy married woman, and was confined at the end of the seventh month of pregnancy. The fœtus was born alive, and Mr Norton observed that it continued to breathe for a quarter of an hour after birth, and the pulsations of the heart were perceptible for three quarters of an hour.

The fœtus measured not quite a foot from the vertex to the right heel when the right leg was extended, but its shortness was due, to a great extent, to spinal deformity; the limbs were plump and the thorax broad. The head was well formed, measuring $3\frac{3}{4}$ inches antero-posteriorly, and $2\frac{3}{4}$ inches between the parietal eminences. There was neither meningocele nor deformity of the face, lips, or any part of the palate. Spina bifida existed in the lower lumbar region, forming a globular projection under the skin 2 inches in diameter; the bodies of the upper lumbar vertebræ were rotated to the left, and the entire lumbar spine much curved laterally, with its convexity to the right. The integument of the thorax showed, when fresh, a distinct pale cicatricial line extending from the neck, along the right of the sternum, to the upper border of the fissure in the abdomen. The lungs were normal, and the pericardium distinct from the pleuræ, the ductus arteriosus and foramen ovale cordis were both patent. The diaphragm and thoracic walls were complete, the pharynx and œsophagus pervious. The left lower extremity

was somewhat thinner than the right, and the left foot, though not arrested in growth, was deformed by talipes equino-varus.

In the front of the abdomen were two great oval apertures completely separated by a narrow bridge of integument, which included, somewhat to the left of the median line, the umbilicus. The orifice of the umbilical vein was patent, and a stout probe could be passed along that vessel as far as to the liver. The upper aperture was the greater, its border was completely lined by the amnion which blended with the peritoneum very intimately, and with the integument by a reddish, slightly elevated line of demarcation. The amnion hung like an apron over the abdominal viscera. The liver was normal, and several inches of intestine could be traced from the stomach to the abnormal blind termination of the intestinal canal presently to be described. The entire canal, including the stomach, was held loosely to the back part of the abdomen by a simple mesentery, and no great omentum existed. The umbilical vein formed an abnormally deep fold in the peritoneum. The spleen was connected with the stomach by the usual serous fold, and the dilated right kidney had apparently pushed itself forwards into a fold of peritoneum which partially invested its posterior surface.

Below the bridge of skin containing the umbilicus was another aperture, shown in fig. 1, oval, and over 2 inches in horizontal diameter, by 1½ inch, measured vertically. There was a considerable area of integument between it and the symphysis, where the ossa pubis were nearly 1 inch apart. A few lines below the prominence which marked the spine of the left os pubis, and beyond the fold of the groin, was a minute but pervious opening (*g*), and ¼ of an inch external to this opening was a small flap of skin, placed completely on the front of the thigh. There was a similar flap on the right side ¼ of an inch below the spine of the right os pubis. These flaps appeared to consist of erectile tissue, and appeared to represent the labia minora.

The great oval aperture below the umbilicus merited particularly careful observation and dissection. It was not a large hole opening freely into the abdominal cavity, like that above the umbilicus. The integument was entirely deficient, but the

gap was covered in by a very thick aponeurosis from the abdominal muscles, often seen in this kind of malformation. The integumental edges of the aperture overhung this aponeurotic floor, on the surface of which was the bladder, represented by two oval elevated and sharply-bordered patches of corrugated mucous membrane, each covering a disc of muscular tissue (fig. 1, *b′*, *b*.). These two half-bladders, as they may conveniently be termed, were separated by ½ of an inch of smooth, shiny tissue, which lined the entire floor, excepting that part occupied by these vesical elements. In the upper part of the smooth tract between them was a circular aperture (*d*) ¼ of an inch wide when gently stretched; it communicated with the intestine above by a narrow elliptical opening, and led directly into the intestine below, which ended as a blind extremity 1 inch beyond the aperture. The mucous membrane of the intestine to the very blind extremity was marked with well-formed valvulæ conniventes.

On the upper and outer border of the right half-bladder was an opening $\frac{1}{10}$ of an inch in diameter (*e*). This I naturally took for the orifice of the ureter, but further dissection showed that it communicated with a right half-uterus. Close to the lower and inner border of the left half-bladder was a prominent nipple-like projection ⅛ of an inch long (*f*), the vesical mucous membrane was continued on to its sides, and its apex was perforated by the orifice of a canal. The projection appeared like an abnormal termination of the left ureter, but on passing a probe into the canal, that instrument could readily be made to appear out of the opening below the left groin; in fact, the canal was complete throughout, as will presently be explained. On the smooth tissue external to each half-bladder, a very faint depression (*c*, *c′*) marked the lower end of each of the ureters, here quite impervious.

Turning to the deep dissection of the abdomen, I found not only curvature in the lumbar region, but also great distortion of the sacrum, which was curved upwards to such an extent that the tip of the coccyx was high above the level of the brim of the pelvis. A stout ligamentous band passed between the coccyx and the ligament which connected the gaping pubic bones. Hence the cavity of the true pelvis was divided into

two shallow depressions. Into the right nothing passed but vessels representing the branches of the internal iliac artery; the left half of the pelvic cavity transmitted a curved tube, 1 inch in length and $\frac{1}{8}$ of an inch in calibre throughout. This tube connected the nipple-like projection close to the left half-bladder with the opening below the left groin. It was lined with mucous membrane and filled with sebaceous matter.

The abdominal aorta exhibited marked anomalies in its branches. The sketch shows the peculiarities as far as I could precisely certify by dissection; I leave out the phrenic mesenterics, supra-renal, spermatic, and sacra media arteries, since I failed to trace them. The cœliac axis was given off $\frac{1}{2}$ an inch below the diaphragm, and at almost the same point the aorta divided into a right common iliac artery $\frac{1}{8}$ of an inch in diameter, and a left, hardly one-third as wide. The right was really the aorta directly continued downwards, the left iliac was given off at a wide angle from the parent trunk. After running for nearly $\frac{3}{4}$ of an inch and giving off the right renal artery, the right common iliac divided into three branches, namely, a long and very broad right hypogastric, a slender right external iliac, and a still narrower left hypogastric, which gave off three pelvic branches representing some of the divisions of the normal internal iliac, and also, like the right hypogastric, sent a twig to the rudimentary and cloven bladder. These hypogastrics ran in the stout aponeurosis behind the lower integumental aperture in the abdomen, up to the umbilicus. The left common iliac was short owing to the great distortion of the lumbar spine; it divided into a left external iliac branch, and a left internal iliac remarkable for giving off the left renal artery.

The right kidney was dilated, forming a cyst 2 inches long by $1\frac{1}{2}$ inch broad; its lobular structure was still apparent. The ureter was 3·9 inches long, and uniformly $\frac{1}{5}$ of an inch in calibre, and quite pervious from the renal pelvis to within $\frac{1}{8}$ of an inch of the bladder, where it was reduced to a mere fibrous cord that passed through the aponeurosis, and could be traced in front as an almost imperceptible linear depression external to the elevated right half-bladder. The left kidney was 1·9 inches in vertical diameter, and 0·6 inch broad, its ureter 3 inches long and nearly $\frac{1}{4}$ of an inch broad throughout, excepting close to the

lower end where, like its fellow, it was reduced to an impervious fibrous cord. This cord passed in front of the rudimentary left half-uterus, and ended as an almost imperceptible depression on the smooth surface external to the left half-bladder.

Searching for the internal generative organs, the sex of the fœtus became evident on a glance at the conspicuous structure on the left side, behind the lateral abdominal wall (fig. 3). It looked at first like an entire uterus and appendages, rather unsymmetrical, yet complete. Further dissection showed that it represented only half the internal organs, but remarkably well-finished as to ovary and tube, considering the condition of the corresponding parts on the right side.

In fact, the internal genitals showed a strange "mis-building," as a German would say, for it was evident that the ducts of Müller had never united, and the right duct had developed into the semblance of the right organs of an *Ornithorhynchus*, non-development of the ovary included. The left duct had tried, as it were, to become one-half of a placental mammal's organs, but the effort appeared to have been too much, and the body of the uterus was a decided failure. Lastly, the integumental involution that ought to have met the end of the alimentary canal has failed to do so, and has opened of itself, as the nipple-like process above described, into the urogenital sinus (as represented by the lower abdominal aperture) missing even the pervious canal of the right internal organs.

I will now describe these malformed organs more specially. The right internal genitals were represented by a curved tube nearly 2 inches long (fig. 4). The first inch (*a*) was fusiform and very thick walled; its cavity, lined with corrugated mucous membrane, opened on to the border of the right half-bladder, as above described. It bore a strong resemblance to one of the uteri of a *Didelphys*, and similar malformations have been figured and described by Kussmaul,[1] Förster,[2] and others. There was no distinction between uterus and vagina. Beyond this half-uterus was a flat, button-like projection, over $\frac{3}{10}$ of an inch in diameter; it was perforated by two foramina (*c*, *d*), entirely separated by a thick septum. The more internal foramen led

[1] *Van dem Mangel, &c., der Gebärmutter*, Wurzburg, 1859, chaps. vi. and vii.
[2] *Der Missbildungen des Menschen*, 1861.

into the uterine cavity, and hence communicated with the opening near the bladder. The more external passed into a canal which tunneled the remainder of the tube (*e*) for nearly ½ an inch, where the tube suddenly became impervious, and ended in a thin cord (*f*) with small but very distinct fimbriæ at its extremity (*g*); there was an opening in the midst of the fimbriæ admitting a bristle almost as far as to the end of the thick part of the tube. Close to this fimbriated extremity was a minute solid body (*h*) which I may liken in size to the "millet seed," so familiar to the pathologist as an object of comparison. The entire curved tube, representing the right duct of Müller, was held to the back of the right lateral abdominal wall by a short, but distinct fold of peritoneum.

On the left side, also provided with a fold of peritoneum, were the representatives of the left duct of Müller (fig. 3). This primitive canal had not developed inferiorly to such an extent as on the right side, for the vagina and body of the uterus were represented by a flat, fibrous band, inserted into the aponeurosis behind the left half-bladder. On the other hand, the upper end was as forward and as perfect as in a normal fœtus, for the fimbriated extremity of the Fallopian tube was well-developed and the ovary was present, measuring 0·4 inches in length. The tube was much contorted and dilated at the point where it joined the band representing the uterus; a kind of diverticulum, with a blind depression on its surface, appeared to represent the fundus uteri.

Out of the above abnormalities, two require more special consideration. I refer to the button-like projection on the surface of the right internal organs, and to the remarkable curved tube (fig. 5, *i*) in the pelvis. There cannot be much doubt that the first portion (fig. 4, *a*) of the right internal organs represents the uterus and, perhaps, part of the vagina. Again, the fimbriæ (*g*) settle the nature of the opposite end of the organs. Is the projection, with the apertures (*c* and *d*) an abnormality of the uterus or of the Fallopian tube? I believe that it is tubal, not uterine. Rokitansky describes certain accessory openings in the tube, in his *Lehrbuch*. He most frequently found them on the summit of a round projection on the tube, which is generally more or less contracted and bent at the same point. It is

generally admitted that the original free end of Müller's duct is represented in the adult by the "hydatid of Morgagni" that hangs from the fimbriæ. The opening is formed by a splitting of the tube below the free end; and Klob, in his *Pathologische Anatomie der Weiblichen Sexualorgane*, compares the fimbriæ to carunculæ myrtiformes. In my specimen the fissure must have originally been very long, its edges have developed fimbriæ normally at the extremity of the tube, and closed along *f* and *e*, fig. 4, but at the innermost extremity the fissure has remained open, the whole tube closing in, however, at one point —that is to say, between *c* and *d*. That *c* and *d* are apertures in the tube there can be little further doubt, when we bear in mind that they open into the peritoneal cavity, like the normal fimbriated extremity; and the complete interruption of the canal of the tube by the septum between *c* and *d*, appears to confirm my opinion, expressed above, that the tube has closed in across the proximal end of some previous fissure, which has itself remained open at *c* and *d*. This tendency of the fissure to close irregularly is further seen in the complete stricture of the tube at the point where the thick segment (*e*) meets the thin, but equally pervious portion (*f*). Though the distance from *c* to *g* is great, this need not make it appear improbable that one single fissure once extended from *c* to the true opening of the tube in the midst of the fimbriæ, since *e* and *f* could have attained their present length after the establishment of the anomaly.

What is the nature of the tube *i* (fig. 5) which extends from the projection *f* (fig. 1) close to the left half-bladder, to the opening *g* (fig. 1) in the groin? Is it an anus that has pushed itself far upwards to meet a rectum that has never been developed? I think not, for in cases of absence or imperfect formation of that part of the alimentary canal the anus itself is, as a rule at least, hardly so much as indicated. In this case I believe that the anal involution of integument at the cloaca, has never existed, or rather that *g* (fig. 1) is a cloaca, which, however, through failure of development of both vagina and rectum, has only a long, abnormal urethra—the tube *i* (fig. 5) opening into it. In fig. 1, *b* and *b′* represent the fundus of the bladder, but the smoother surface between the impervious attachment of

the ureters at *c* and *c'* and the projection at *f*, must be considered as the trigone. If so, the elements of the fundus and trigone have in this case been completely arrested in development, whilst the true female urethra, the tube *i* (fig. 5), has not only become a perfect tube, but has grown to an unnatural length, and alone of the three tubes that ought to have opened at the cloaca, has succeeded in so doing.

Failure of union of the visceral plates in the abdominal region, arrested development of the intra-abdominal part of the allantois, and persistence of a primitive condition of the alimentary tube in the region of the omphalo-mesenteric duct will account for the protrusion of the viscera, the condition of the bladder, and the opening of the intestine by an aperture far above its blind extremity and above the imperfect vesical elements. It is needless for me to give a summary of the normal development of the alimentary and genito-urinary tracts. The relation of this process to malformations of the bladder has recently been discussed at great length by Dr F. H. Champneys, in a monograph [1] which includes a very complete synopsis of all previous dissections throwing light on the subject, and of all reasonable theories on the question.

It is hardly correct to include this monstrosity on Förster's system of classification,[2] as an example of a "cloaca" in man. Such a term must be used homologically, not analogically. No observer could compare the great aperture in my specimen to the normal condition of the alimentary and genito-urinary outlets in a fish; he would have to rely on one fact alone—the opening of the intestinal canal in front (*i.e.*, above, in a human fœtus) of the vesical and external genital elements. It would be still more absurd to consider this monster to be monotrematous or sauropsidan in its alimentary and genital organs. On the other hand, in a human subject, where the rectum opens into a normal vagina, a true cloaca may be said to exist, although the parts never precisely resemble their homologues in monotremata and sauropsida. Then, could a human monster be found—I have never discovered any record of such a malforma-

[1] "A Case of Extroversion of the Bladder in a Female Child," with Dissection (*St Bartholomew's Hospital Reports*, vol. xiii. 1877).

[2] *Op. cit.*

tion—where the ureters and Fallopian tubes open at *g* (fig. 1), and where the intestinal orifice *d* opens immediately in front of *g*, there we would have a truly icthyopsidan condition.

In short, this fœtus which I dissected is an example of extreme arrest of development, not even symmetrical, with subsequent partial distortion of some of the imperfectly-formed parts. It is therefore interesting, more as an example of perverted development, than as an illustration of any morphological question.

Explanation of Plate XIX.

Genito-Urinary Organs from a Case of Fissure of the Abdominal Walls.

Fig. 1. General view, semi-diagramatic. *a*, Fringe of amnion attached to lower border of upper abdominal aperture; *a′*, umbilicus and patent orifice of umbilical vein; *b*, right, and *b′*, left half bladder; *c*, *c′*, depressions indicating attachments of impervious ends of ureters; *d*, aperture communicating with intestine, the horizontal slit marks the opening of the intestine above this aperture; *e*, opening of right half uterus; *f*, opening in nipple-like projection communicating by a canal with *g*, opening in integument below left groin; *h*, *h′*, labia interna; *x*, *x*, mark position of each os pubis.

Fig. 2. Plan of the branches of the abdominal aorta. *a*, Undivided trunk of aorta; *b*, cœliac axis; *c*, right common iliac artery; *d*, left common iliac; *e*, right renal; *f*, right hypogastric; *g*, right external iliac; *h*, left hypogastric, giving off three pelvic branches; *i*, left external iliac; *k*, left internal iliac; *l*, left renal artery.

Fig. 3. Left ovary, Fallopian tube and uterus. The body of the uterus is represented by a fibrous band. × 2.

Fig. 4. Right internal organs. *a*, Right half uterus, laid open to show its thick walls and cavity, *b*, which opens at the aperture, *c*, in the button-like projection; *d*, second aperture in the same projection communicating with canal in *e*; *e*, *f*, wide and narrow parts of Fallopian tube; *g*, fimbriated extremity; *h*, rudimentary ovary (?).

Fig. 5. Diagram of parts behind the structures shown in fig. 1. The position of the right half bladder is indicated by the dotted circle *a*, of the left by *a′*; *b*, ileum; *c*, blind end of alimentary canal; *d*, site of *d*, fig. 1, from behind; *e*, left, and *f*, right half of internal sexual organs; *g*, end of pervious portion of left ureter, the impervious part passes in front of the rudimentary uterus to its attachment; *h*, junction of pervious and impervious portions of right ureter; *i*, canal opening at *f* and *g*, fig. 1.

DESCRIPTION OF A POLYGRAPH (with Figure).

BY DAVID NEWMAN, M.B.

THE instrument, a representation of which is shown in the woodcut, was devised for the purpose of taking simultaneous tracings of the heart's impulses and the respiratory movements. For the sake of description it may be divided into two portions: (1) the transmitting, and (2) the recording. We shall first describe the former of these. Owing to the difficulty of tracing the movements of the heart and thoracic wall by any direct method, we were compelled to employ Marey's tambours, although we are aware that there are certain objections to this mode of transmitting and recording impressions. The tambours (J) are fixed to a brass plate (M) by means of two horizontal bars (X). These bars may be moved from right to left along a slot in the brass plate, and fastened in position by a pinching-screw (K); by altering the length of the levers (L), tracings of various dimensions may be obtained; whilst, by the same arrangement, the pens may be adjusted so that simultaneous movements are recorded on the paper in the same line. The tube (T) communicates with the cardiograph, while (V) passes to the pneumograph. The recording portion of the apparatus is very simple. Coiled on the drum (A) is a ribbon of paper (G) about two inches broad. The paper, on leaving the drum, slides over a flat stage (B), and then passes between two rollers (C and D). The stage (B) may be elevated or depressed, so as to suit the height of the paper on the drum, and fastened in position by the screw (I). The plane roller (C) is made to revolve from right to left by means of clock-work placed on the other side of the brass plate (M). The purpose of the double-flanged roller (D) is simply to keep the paper in contact with the plane roller (C). By altering the size of the plane roller, the paper may be made to move at various rates, as desired. The movement of the paper may be stopped without interfering with the clock-work, by turning the eccentric (H), from right to left, when, by pressing back the roller (D), the paper will be relieved from its contact with C;

and so, although C still revolves, the paper will remain stationary. The spring (F) presses upon the axle of A, in order to

DESCRIPTION OF PLATE.

J, tambours; X, horizontal bars, sliding in slot, and fastened by screw K; T, tube to cardiograph; V, tube to pneumograph; L, levers; A, drum of paper; B, stage; C, plane roller moved by clock-work; D, flanged roller; E, spring for pressing D against C; F, spring controlling A; G, ribbon of paper; H, eccentric for pressing back D; I, pinching-screw, for fixing stage; M, brass plate supported on wooden stand W. Scale $\frac{1}{4}$.

retard its movement sufficiently to keep the paper stretched as it passes over the stage (B), where it is written upon by the pens. The pens consist of small pieces of glass tubing (sufficiently

large to hold a drop of ink), with a capillary prolongation, through which a fine cotton thread is passed. The pens having been charged, the ink passes down the thread, and is transferred from it to the paper, without the point of the tube touching the paper; the friction is, therefore, extremely slight. By using inks of various colours, movements which closely resemble one another in appearance may be distinguished at a glance. If required, time may be recorded alongside the tracings.

REMARKS ON THE MECHANISM OF THE SECRETION OF SWEAT. By C. HANDFIELD JONES, M.B. Cantab., F.R.S., *Physician to St Mary's Hospital.*

IT seems almost unwarrantable for a mere bystander to take exception on grounds patent to common observation to the exact inquiries of working physiologists. And yet the physician, who accepts gratefully every ray of light which can be thrown on the nature of the vital processes, which he endeavours to order and control, is obliged to consider always whether views which appear to be established by laboratory research are verified when transferred to the region of clinical observation. In not a few familiar instances this can be done, with great advantage to the practice of medicine. Where this is not so the practitioner is obliged, not indeed to deny the truth of the conclusions arrived at by scientific workers, but to doubt their applicability to the human subject. If experimental results do not show some close correspondence with bedside phenomena, it is impossible to use them for the elucidation of the latter.

The object of the present communication is to inquire how the case stands with respect to recent investigations into the process of sweating. Experiments seem to have established that a copious discharge of sweat can be induced in the feet of the cat or dog by stimulation of the sciatic or brachial nerves, and this, too, independently of the usual blood-supply. It may not be clear whether this view is intended to be exclusive, and to affirm that sweating is produced in this way and no other. But if this be so, and sweating is regarded as dependent on an action of certain nerves, there are some common, but very significant facts, which can hardly be ignored. I refer to the influence of strong exercise, sleep, heat, general debility, rickets, impending syncope, and vasomotor paralysis. These are sufficiently various conditions, and it cannot be otherwise than instructive to inquire how they come to produce the same results.

Before attempting this, however, I would make a few remarks

upon a familiar experience, which, so far as I know, has not yet been explained. I allude to the effect of warming our limbs by exercise. If a person has irritable arteries—as I had when young—his hands and feet in cold weather may be cold, and the superficial vessels empty after sitting still some time, but with exercise they will become warm and the vessels well-filled. No doubt the exercise increases the action of the heart, but that this *per se* is not a sufficient cause is shown by instances where exercise has no effect in warming the limb (see Paget's *Clin. Lect.* p. 184), and by the much greater effect of exercise in warm than in cold weather. In the remarkable case of hyperæmia affecting the legs of a young female recorded by Graves (see *Clin. Lect.* p. 868), it is specially mentioned that walking much about the room brought on the hot fit in her limbs immediately. This is quite consonant to the ordinary effect of exercise, and might be ascribed to increased action of the heart, but that the limbs were not affected simultaneously but successively, one being cold, pale, and painless, while the other was hot, darkish, and painful. Of course this alternation excludes any influence of the heart in the causation of the phenomena. The same conclusion must be drawn from the limitation of the affection to the feet and lower half of legs. The best explanation of the matter, I think, is founded on the fact that excitation of any nervous centre is apt to cause more or less paresis of other nervous centres with which it is connected. Of this the debility and mental impairment caused by sexual excess is a good example, and so is the following experience related by Mr Wills in his *High Alps*, p. 185:—"We found what we always knew to be a sure sign of latent fatigue, that our powers of observation were much impaired. He remarked to Balmat (his guide) the day after crossing a high col: how is this, I notice neither flowers, nor rocks, nor anything else to-day? Balmat replied that he had often observed the same thing himself—'Après une grande course on ne remarque pas beaucoup les objets.' I thought for a day or two afterwards that Balmat spoke low and indistinctly, and taxed him with it, but he assured me that the fault was mine. I was deaf, also not an unusual consequence of 'grandes courses.'" Here the prolonged exertion of the motor centres induced a paresis of the intellectual and

auditory, lasting some time after the former had ceased. The feverishness induced by over-exertion, and syncope from the same cause, are also instances to the same effect, the heat regulating and cardiac centres being rendered paretic by the overstrain of the musculo-motor (see Wunderlich, p. 155 *Syd. Soc.*). I have stated this view in my work (p. 17), and it is one of no little importance in practical medicine. It constitutes the foundation of the fatigue treatment of insanity, and of Tronchin's success with Parisian hyperæsthetic dames by getting them to polish their own parquets. Applying then this view to the case of exercise, I remark that there can be no error in assuming that a large amount of nerve-force is expended in muscular exertion. The large motor cells of the cord are (to speak metaphorically) drained of their force by keeping the great muscles of the limbs at work, and therefore cannot supply adequately the vasal nerves of the nutrient arteries, which consequently dilate and admit more blood. The arterioles of the covering skin will naturally be affected in the same way. The nearest vasal nerves will probably first suffer, but if the tonicity of the vascular system generally is low, other and more remote nerve tracts will speedily be involved. If the exercise be very prolonged some amount of œdema from loss of capillary retentivity will occur, and in the kidneys this may cause albuminuria with hyaline and granular casts (see Weston's Walk). If circumstances are favourable (the surface not chilled) the increased blood-flow will extend to the sweat-glands, and excite them to increased action. The above theory seems to me to deserve some consideration, as affording a rationale of the production of sweating by strong exercise, which is certainly a means in most persons of very considerable potency in this direction. It is very noteworthy that the head is apt to perspire much more profusely than the axillæ or other parts; that, in fact, the flux does not occur nearly so much in those districts where the nerves are energetically at work as in those where they are comparatively at rest. On the modern view one would expect that the sweating would be most profuse on the lower limbs, whose nerve muscular apparatus is in full play, and would be almost *nil* on the scalp, where little or no muscular action is going on. The motor impulses descending by the crural or sciatic nerve

should stimulate the sweat-glands of the legs and feet to much greater action than those of other parts. But this is not the case. The reason why sweating is so profuse about the head is, I imagine, that it is so freely supplied with blood, and is so near to the heart, that the blood-pressure there is materially greater than in more distant parts. There is no reason to think that the sweat-glands are more abundant in the scalp than elsewhere. From the above, I conclude that *excessive expenditure of nerve-force* is the main feature in sweating from exercise.

Sleep, the very opposite condition to the foregoing, produces in debilitated persons, not by any means in the phthisical only, the very same effect. Watson remarks that the perspiration of phthisis seems to have a close connection with the sleep of the patient; it seldom comes on while he continues awake. He notices also that the perspiration is generally most copious on the upper part of the body,—the chest and the head. In rickets it is noted by observers that the copious perspirations of the head occur especially during sleep, though they are not infrequent at other times. The main feature in sleep is *the non-developement of nerve-force.*

The tendency of *heat* to cause sweating is familiar to all. That this agent, if at all excessive, greatly enfeebles the nervous system cannot, I suppose, be questioned. Writers speak of tropical heat as rendering many, particularly those who enter the tropics for the first time, unable to exert themselves in the least, either physically or mentally. I shall never forget the utter prostration I experienced one summer while staying a few days at the Lake of Como, and the rapid improvement which ensued on ascending to the Engadine. Heat certainly tends *to abolish nerve-force.*

The influence of *general debility* is equally certain, and may be illustrated by the following facts:—Swiss guides have informed me that they sweat much more in the first "course" or two, at the beginning of the season, than they do afterwards when they have got into better training. It is much the same with horses. "Our horses must have oats, the oats must be in them," remarked an English omnibus driver to Professor Playfair. "If they come from the farmer they are round and plump, for the farmers feed them well. But such horses are

not fit for use. They sweat directly, and cannot bear a hard run. The oats must be in them." *Rickets* is certainly a disease in which general debility is strikingly apparent, and profuse sweating, as already stated, is one of its most marked features. Mothers use the strongest terms to express the amount of the perspiration. It is not confined to severe cases only. A lad at a public school had for some time such copious night sweats that his shirt used to be quite wet, yet he was not laid up. He bears evident indications of bypast rickets. *Impending syncope*, and the prostration *caused by tartar emetic*, and sometimes *influenzal catarrh*, are other conditions where nerve-force is for the time greatly depressed, while sweating is profuse, and it is certainly most probable that these events are not mere coincidences. In a case of severe catarrhal sore-throat, with roseolous rash, under my care, the patient, aet. 28, a weakly male, had one night such profuse sweating that at twelve and four he had to get up and change his night-shirt, which was quite saturated.

Division of vasal nerves has been found by various experimenters to promote sweating. Dr Ord (*St Thomas's Hospital Reports*, 1873) records a case of paralysis of the sympathetic in a child aet. 15 months. The face on the right side flushed and sweated, the right eye watered, the right nostril had a constant running, while the left side was the reverse in all these respects. Both sides were equally developed.

The various agents now noticed, which produce copious diaphoresis, agree in this respect, and in this alone, that they all enfeeble nerve-centres; and, to say the very least, are likely to paralyse vasal nerves. Either they cause excessive consumption of nerve-force, or hinder temporarily the generation of it, or render the system less capable of producing it, or interfere with its conduction to certain districts. I cannot but regard the possibility of explaining the action of all these agents, differing so widely as they do, on one common ground, as a considerable argument in favour of the view I advocate. The circumstance, often verified by Alpine climbers ascending from a hot valley to the bracing snow-fields, that the very opposite to one of the above noticed agents, viz., cold, can arrest the sweating of exercise seems to me no inconsiderable proof that the latter is

produced as I have described. Cold assuredly contracts vessels, acting no doubt reflexly on the vasal through sensory nerves. If exercise did not act by paralysing the vasomotor, but by stimulating the glandular, why should cold arrest its effect? On the view that "local mechanisms" are the regulators of the circulation in glands and other parts, it might be contended that inhibition of these by nerves analogous to the chorda tympani was essential to the act of secretion, and that such inhibition implies stimulation. But when nerve-power is failing everywhere, where is stimulation to be found? And why should not the local mechanisms, nerve-centres themselves, participate in the general nerve paresis? To these questions I doubt if any satisfactory answer can be given.

The conclusion which I adopt is, that in the great majority of ordinary instances of sweating the process is essentially one of vasomotor nerve paresis. But this does not exclude the possibility of the process being occasionally otherwise conducted. Certain drugs, such as jaborandi, without causing notable depression of nerve-force, may act directly on the gland-cells and stimulate them to increased action, just as urea or sodic nitrate do the renal. Occasionally, also, glandular nerves being excited in some way may produce the same result. But these are not the ordinary methods by which sweat-gland activity is evoked.

ON AN ANOMALOUS BEARING PILOSE SKIN IN THE PHARYNX OF A YOUNG WOMAN.

By P. S. Abraham, M.A., B.Sc., F.R.C.S.I., *Curator of the Museum, Royal College of Surgeons in Ireland.* (With Figure.)

On the 20th of July a small tumour, freshly excised, was brought to me by Mr Barton, F.R.C.S.I., Surgeon to the Adelaide Hospital in Dublin. Sub-ovoid in shape, both in side view and in horizontal projection, it measured in length 32 mm., in breadth 15 mm., and 20 mm. in height—*i.e.*, from its base to its broadened-out apex. A rod-like nodule of cartilage, seen in section in the base, occupies its centre; and on near inspection the whole surface is seen to be covered with a close growth of delicate pale hairs. The other naked-eye characters are well-described in the following history, account of operation, and remarks on the case, with which Mr Barton has been kind enough to furnish me for publication:—

"Margaret McC——, aged twenty-two, a domestic servant, was brought by her mistress to me on the 19th of July last, complaining of difficulty of swallowing, and a sense of pain and fulness in her ears and head, which she attributed to a growth in her throat, which she stated had much increased lately. Upon opening the mouth widely and depressing the tongue, a tumour was seen occupying the pharynx, about the size of the last joint of the thumb of an adult hand. It was white or skin colour, and contrasted strangely with the red colour of the velum and fauces. Upon introducing my finger, I felt that the tumour was pendulous and narrower above than where it appeared below the velum. It seemed to hang from the basilar process of the occipital bone or roof of the pharynx. The girl stated that, as far as she knew, it had always been there, but had not caused her any annoyance until lately, when it began to increase in size. I admitted her to the hospital, and next morning proceeded to remove the tumour.

"The mouth being held well open, I found no difficulty in

placing the wire of an écraseur round the base or narrowest part of the tumour. I then seized the lower part of the growth with a vulsellum, and gradually tightened the wire. Here, however, I was met by a difficulty. The structure of the growth proved so tough and unyielding, that the wire broke before it had done more than tightly constrict the pedicle. Withdrawing the écraseur, but leaving the wire tight round the pedicle, I cut off the growth with a blunt-pointed curved scissors, and next day removed the loop of wire. The patient left the hospital three days afterwards, quite relieved of the symptoms she had complained of; and I have heard of her since,—that she continues quite well.

"The appearance presented by this tumour was very remarkable, and quite different from anything I had previously seen. The growth nearly filled the space between the pillars of the fauces, and contrasted strongly both in colour and surface with the velum under which it appeared and the fauces on either side of it. The sensation given to the finger when passed round it was that of a soft skin-covered tumour, and contrasted markedly in this respect also with the mucous surface around.

"After the amputation of the growth nothing could be seen upon looking into the mouth, as it was cut off close to the velum; but the finger, when introduced, could readily distinguish the stumps of the tumour above and to the left side, and trace it upwards as far as the posterior nerves, but could not make out more particularly the point of origin. The passage of the nose was free. (Signed) JOHN K. BARTON."

"October 1880."

A small slice from the region of the neck of the tumour was suitably hardened, and sections for the microscope prepared and examined. The nodule of cartilage occupying the centre of the growth is of what may be called a fibro-cellular variety, having the cells large and closely packed, with but scanty intercellular matrix, the fibrous structure of which can be with difficulty made out. In many places the matrix seems to be simply coarsely granular.

Surrounding the cartilage and passing gradually into it, without definite line of demarcation, is a layer of spindle-celled connective

tissue. The gradual passage of the one tissue into the other is well shown, the spindle-shaped cells gradually swelling out, taking on the typical cartilage-cell form, and then commencing to multiply in the usual way. The spindle growth in its turn passes still more gradually into an ordinary areolar connective, and this again soon becomes mingled with adipose tissue, which in the main makes up the substance of the tumour. Numerous fibrous bands, however, and bundles of striped muscle fibres, as well as many blood-vessels, pass through the whole in various directions. The preparation shows no nervous elements.

Tumour covered with pilose skin from the pharynx of a girl.

As was to be expected from its macroscopic appearance, the integument of the growth proves to be composed of ordinary cutaneous tissue, showing epidermis, corium, numerous hairs in their typical follicles, well-developed sebaceous glands, and less numerous sudoriparous glands. All these structures present but slight changes from their normal development. In the epidermis there is some hyperplasia of cellular growth; the corneous layer, for instance, is everywhere of great thickness, and is particularly abundant at the mouths of the hair follicles, where the scales have a tendency to take on a swollen condition. That the superficial cells in a pharyngeal growth should become corneous at all is a remarkable fact; but it must be remembered that they would there be in the track of the inspired air. Their great abundance may probably be due to the lack of attrition in such a situation. The rete Malpighii is also well formed, with elongated columnar basal layer, which has taken up the logwood dye in a marked manner. In places there seems to be a suspicious invasion of the neighbouring cutis by apparently epithelial cells. The deeper cells of the rete, although dark, do not appear to be pigmented; but the cells of the strata granulosum and lucidum possess

blackish granules both within and around them—possibly obtained from the respired air as it passed. The corium, with its papillæ, is highly vascular, and is closely traversed by the hair-bearing follicles which typically show their normal structure. The hairs are delicate, slender, and non-pigmented. The sebaceous glands appear to be mostly two for each follicle, into which they often open at different levels—sometimes one near the orifice or sometimes close to the bulb. The mouths of some of the follicles are occluded by masses of round cells—probably the slightly modified secretion of these glands. The sudoriparous glands also show their ordinary structure, with the coiled glandular portion situated in the subcutaneous tissue. Parts of the tumour show considerable infiltration of small-celled indifferent tissue, as well as other evidence of active growth; and the above-mentioned doubtful commencing ingrowth of epithelial elements points to a possibility of malignancy; at the same time, the history shows that it was there for years, and that it was probably congenital.

The difficulty of conceiving how or why a portion of pharyngeal mucous membrane should assume the almost complete character and function of a piece of true skin, leads me to suggest that we perhaps have here an example of a kind of atavism of tissue. The tumour grew from the top of the pharynx, near to the basilar suture—*i.e.*, in the line of the epiblastic ingrowth which in the developing fœtus went to form a portion of the pituitary body. Have some of these epiblastic cells remained and multiplied with epidermic character?

In the *Dublin Hospital Gazette* for 1856, p. 82, under the title "Description of a Monster by Excess of Development," Dr G. H. Kidd describes a tumour which grew from the palate of a newly-born child, and protruded from its mouth. As suffocation of the infant was imminent the growth was removed. "The mass was of an oval figure, and had been attached to the palate by its small end; it measured 8 inches in length, and between 5 and 6 at its broadest part. It was divided on its surface into a number of lobes, without any definite arrangement, varying in size and colour, for the most part covered with well-formed skin, and of a solid structure." Further examination showed that the tumour included imperfectly developed portions of fœtal struc-

tures. One of the lobes contained rudiments of intestine, others had within them fragments of bone and cartilage. Indeed, the excess of development had proceeded to a much greater extent than in the subject of this paper. I have not found any other record of a skin-covered pharyngeal growth.

P.S.—Since writing the above, I have had an opportunity of examining the pharynx of the young woman, with the help of the laryngoscopic mirror. Three patches, one about the size of a threepenny piece, and several small spots of the white tissue, are to be seen anteriorly and below the left Eustachian opening—the largest one being probably the remains of the pedicle. It thus becomes almost certain that the tumour had grown from the margin of the Eustachian cartilage. The mucous membrane in the neighbourhood is thickened and swollen, and has to the finger the feel of a tonsil, with rough spots. The nasal passages present nothing abnormal, except that the inferior meati are particularly small. There seems to be no absence of the inferior turbinated bone, which, to account for the possibly excessive dryness of the inspired air, I suspected might have been the case.

THE HISTOLOGY OF GRANULAR KIDNEY (with Figure).

BY ROBERT SAUNDBY, M.D., Edin.

AMONG the numerous points in the histology of granular kidney which have been the subject of much controversy, not the least important is the question how far the fibroid material, forming so large a portion of the structure of the kidneys in advanced cases of the disease, is the consequence of inflammatory hyperplasia of the intertubular stroma, or indeed whether such a hyperplasia ever takes place at all?

As is well known, Johnson, Moxon, and other pathologists regard the fibroid material as derived from the collapsed walls of atrophied tubes, while Gull and Sutton are particularly cautious not to affirm an inflammatory origin for the "hyalin-fibroid deposit," to the presence of which they ascribe the morbid appearances.

In my paper, published in the *Transactions of the Pathological Society* for 1880, I have endeavoured to elucidate this question of the histology of granular kidney by recording my own observations.

Every one knows who has worked at the kidney that the appearances in many cases are ambiguous, so that, although the extreme frequency of the disease in this district placed me under the most favourable circumstances for studying it, I examined several scores of kidneys before I could meet with organs in such a condition as to leave no doubt on my mind as to the several points in question.

In the paper above referred to I felt no difficulty in describing the changes in the tubules, the Malpighian bodies, and the blood-vessels, but I was not able to say very much about the intertubular stroma. It seemed doubtful to me whether the changes in it were any more than simple swelling, or at most growth of a kind commensurate with the sub-inflammatory state of the circulation in the organ, but not characterised by emigration of leucocytes or proliferation of the connective tissue corpuscles to the extent that has been described by many authors.

Within the last few weeks I have had the good fortune to meet with a case which has thrown a strong light upon this point, and in my opinion affords an explanation of the contradictory descriptions of other observers.

E. B., 34, female, married, was admitted into hospital in a state of coma, with the history of having been suddenly seized with an epileptiform fit. There was no history of any previous attack or of any illness. She died the following morning. At the autopsy the brain appeared pale; the mitral valve was much stenosed; the liver was slightly cirrhosed; the kidneys were of normal size, congested, with slightly adhering capsules, but presenting no diminution of the cortices, no cysts, or obvious thickening of the vessels.

After soaking small pieces of the kidneys for a few days in picric acid, I made some thin sections, which were stained with picro-carmine and mounted in glycerine jelly. These showed evidence of the changes characteristic of granular kidney.

The epithelium of the tubules was proliferating, and many of the latter were filled with brightly stained young cells. The endothelium covering the Malpighian tufts had proliferated, and some of these bodies had undergone complete mucoid degeneration. The vessels were thickened and surrounded by areas of newly formed fibrous tissue containing many nuclei.

But the point which especially interested me was that the intertubular stroma contained numerous lymphoid cells. I have endeavoured to depict them in the accompanying woodcut.

They contrast strongly with the other cell elements of the stroma by staining vividly, and in the absence of any appearance of proliferation in the stroma cells, it is probable they were derived from the blood.

This case seems to me to indicate that the appearance of lymphoid cells in the stroma occurs under the influence of passing attacks of congestion, which are probably of more or less frequent occurrence, and in one of which death may occur as in the present instance.

The reason why these appearances have not been universally recognised is perhaps chiefly because so many of the granular kidneys which are examined by pathologists have been obtained incidentally from the bodies of persons dying from causes quite unconnected with the kidney lesion, but also because when the disease is far advanced and the anatomical structure of the kidney is profoundly altered, it becomes difficult to say what actually is present, and such doubtful preparations are not of much use in the formation of opinions. It is certainly rare, in my experience, to get kidneys which demonstrate the condition so unmistakeably as those from this case.

The present observation confirms the view I have elsewhere endeavoured to support as to the pathology of this condition. The lesion is undoubtedly inflammatory, and not a "degeneration" (Greenfield), or a deposit (Gull and Sutton). It is, moreover, *diffuse*, and not either strictly interstitial (Traube) or parenchymatous. It is a very chronic diffuse inflammatory process, liable to transient exacerbations, and leading to retrogressive metamorphosis of the higher tissues, together with quantitative increase of the lower.

NOTES ON TWO CASES OF CEREBELLAR DISEASE.

By THOMAS OLIVER, M.D., *Physician to the Newcastle-upon-Tyne Infirmary, and Lecturer on Practical Physiology in the University of Durham.*

CEREBELLAR disease is not so uncommon, nor of its symptoms are we so ignorant, that I can offer these as an excuse for the publication of this paper. We all know from the experiments which have been made by Flourens, Ferrier, and others, that the cerebellum is the central organ of co-ordination, and that destruction of part of the organ is followed by effects on the muscular adjustment in accordance with the seat of the lesion. As an indication, however, of what symptoms may or may not appear during the course of cerebellar disease, I have thought that a contrast of two cases might prove of interest.

Patrick G——, a corporation labourer, but formerly (six years ago) a worker in a lead factory, was admitted into the Newcastle Infirmary on the 12th August 1880, complaining of dizziness, and of what he calls the "staggers." It appears that in walking along the street he is seized all at once with a peculiar trembling of the legs and arms, which ends in him falling to the ground. He states that he has never at any time lost his consciousness, and that the convulsive tremors are entirely beyond his control. Once having fallen, it is a matter of extreme difficulty for him to rise, most of the attempts on his part to regain the upright posture resulting in failure. Very frequently when he has fallen he has been placed on his legs again by workmen passing along the street, but further progression thereafter has been a matter of impossibility, unless he has been supported. This tendency to fall down when out of doors has always been observed during the day, for he has been afraid to go out in the evening. He feels the ground perfectly on which he is walking, and appreciates its resistance, and he is sure that it is the convulsive tremors and the dizziness that have always made him fall. At other times, while walking along the street he has been seized by a peculiar form of vertigo, during which he is sensible of a rotatory movement, not only of himself, but of everything around him. This

sensation of movement on the part of himself and others is absent when he is lying in bed. Frequently—perhaps four or five times in the day—he turns right round while walking in the street, and then falls helplessly on the ground. Though this tendency to self-rotation is beyond his control, he is yet perfectly conscious of the fact, that when the rotatory movement begins he will as a consequence fall, and the knowledge of this and its inevitable result—falling—makes him shout for help. The act of rotation, it would appear, is always preceded by a drawing backwards and inwards, of the right foot, and this as the fulcrum of rotation ends in the body turning to the right. He states that he has never on any occasion turned to the left, nor has there been any loss of sight, hearing, or smell. There has been no vomiting during the whole of his illness, nor does there seem to have been anything like conjugation or deviation of the eyes during the act of rotation or falling. Described by himself, his condition is "one of swaying to and fro like a drunken man.' Unaided he is at times perfectly unable even to stand, and inquiry on this point elicits the fact that the direction of his falling is most frequently towards the right side, the next in order of succession being forwards, and on very rare occasions backwards. Peculiar cramp-like pains of extreme severity have at times been felt in the muscles of his limbs, but he has been particularly free from pain in the head, and notably in the back of the head. His sense of taste is normal, but his speech is slow and somewhat thick; for sometime after his illness began he was unintelligible. He has never suffered from venereal disease.

Family History.—Father died in old age, cause unknown, mother is alive and well, two of his brothers died in infancy. Patient has been a healthy man. For the last twenty years he has served in the militia, and it was on his return from Dunbar in the autumn of last year, where he had been undergoing his annual training and where he was comfortably housed, that he began to experience the convulsive tremors in his legs already mentioned.

Present Condition.—There is dilatation of the right pupil compared to the left. Neither, however, responds quickly to the influence of light. There is a little drooping of the left angle of the mouth, with slight flaccidity of the muscles of the left

cheek. Every now and again there is noticed a well-marked quivering of the muscles of the left face, notably of those connected with the angles of the mouth and nose. This fibrillation of muscle is intermittent; it is at times absent, but frequently it is very troublesome, and entirely beyond his control. The muscles of the arms are well-developed, but rather soft; with the left hand the dynamometer registers 90 kilogrammes, with the right 120. On raising himself up in bed it is noticed that the muscles of the arms are sometimes thrown into a state of violent tremor. Sensation in the limbs remains undisturbed; the patient recognises sharp from blunt-pointed instruments, and the part of the body which is touched by them. Protrusion of the tongue brings on the fibrillation of the muscles already mentioned. The tongue itself deviates slightly to the right; its sensation is normal.

On getting out of bed it is noticed that there is a good deal of agitation of the muscles of the arms and legs, and that when he attempts to stand there is the tendency to fall back upon his bed. Closure of the eyes induces falling forwards. Progression is a matter of some difficulty; he sways from side to side, and, but for help, would have fallen towards the right. He cannot turn round without help.

Patellar tendon-reflex and ankle-clonus are completely in abeyance. The superficial reflexes are slightly increased. There is neither paralysis nor atrophy of the muscles of the limbs. On ophthalmoscopic examination being made, it was found that the inner half of each disc was somewhat œdematous.

On September 8th it is noted that there is very marked improvement in the matter of patient's ability to walk and co-ordinate his movements. In walking, however, the feet are lifted somewhat heavily from the floor, and the anterior part of the arch of the foot is made to bear the weight of the body. With his eyes open he can turn round pretty well and fairly quickly, but when closed he still has the tendency to fall. His speech is slow, and monosyllabic; it is a peculiar drawl, which he says is entirely new to him.

From this date he improved. The fibrillation of the muscles of the left cheek disappeared. On the 17th September he was able to walk about in the garden of the Infirmary without

exhibiting the slightest tendency to fall. The muscular power returned to the left arm, so much so, that on one occasion it registered 120 kilogrammes. No improvement, however, was ever noticed in his speech; he continued to speak in monosyllables during all the time he was under observation. On the 6th October, patient, who was walking tolerably well (it is noticed now that the heel is the first which is brought to the ground), and who had complete control over all his movements, expressed the desire to go home, a request which was at once complied with.

This case is of interest, partly from the distinctness in the reeling gait exhibited by patient, and partly on account of the great improvement in his symptoms.

If we are to accept the theory that the cerebellum is the central organ of co-ordination, then I think we have here a case which points very strongly in the direction of lesion of that organ. Destruction of the cerebellum, when sufficient to give rise to symptoms, has no influence whatever in the production of paralysis. There is volitional effort, but the movements executed are so clumsy and so little to the purpose that the patient instantly falls. In G.'s case, there was pretty complete incoordination, for station and locomotion were all but impossible.

Sensation was normal. Had there been anything like altered sensation in the limbs, then that fact, with the absence of patellar tendon reflex, might have been taken as indications of a commencing progressive locomotor ataxia. But the gait when he first came under observation was not ataxic; in walking there was no description of the arc of a circle by either leg, as is so frequently observed in those suffering from posterior sclerosis.

It is possible that the present condition of this patient is less interesting than his ultimate. We have a consensus of symptoms and physical signs, which cause us to believe that he will ultimately become a general paralytic. Hitherto his mind has remained clear, and there have been neither fits of depression nor of undue exaltation. Beyond a feeling of hopefulness in his own case—a hope partly realized in the improvement of symptoms—there has never been any approach to the bragging disposition of those who are suffering from general paralysis, and yet with all this, there have been some of the more usual symptoms present, such

as the fibrillation of the muscles of the cheek when the tongue was protruded, or when attempt was made to speak,—slight paralysis of the tongue which caused him to speak in monosyllables,—inequality of the pupils and a gait in which, while the feet were lifted high they were thrown down forcibly, the heel striking the floor first. This latter point, however, was only noticed after he had been under treatment for some time. Closure of the eyes, while it at first induced falling, had latterly no effect whatever either on station or locomotion. It may be mentioned, however, as against the theory of general paralysis, that while there was slight paralysis of the tongue, his speech, when under observation, though somewhat slow and drawling in its nature, was so clear and distinct in its character, that the patients collected together in the wards frequently asked him to read aloud. There was no loss of that delicate co-ordination of the fingers which makes handwriting a matter of impossibility. He frequently wrote his name in the "Journal" at my request, and, considering his occupation, I think his handwriting will very favourably compare with that of any person who is not in the habit of using the pen.

I am not in a position to state with anything like an approach to certainty what the relationship of states of the cerebellum is to general paralysis. Not long ago I had a patient under my care in whom I diagnosed the existence of a tumour in the base of the brain, and involving in all probability part of the pons. The case, however, went from bad to worse, and as the woman became maniacal, she was removed to Cox Lodge Asylum, where I learned from Dr Whickham, the medical superintendent, that after a residence of a few months she died, and that at the autopsy a tumour of the size of a walnut was found in the pons Varolii, which had produced flattening of one of the lobes of the cerebellum.

As a contrast to the above, the following case, in which there was almost a complete absence of such symptoms as would lead one to infer cerebellar disease, is of more than ordinary interest. For the clinical notes of the case I am indebted to her medical attendant, Dr Purdom. In the months of June and July 1878, Miss H., a young lady of twenty-four, consulted Dr Purdom for an ill-defined pain over the hepatic and

occipital regions. There was also noticed at this time rather rapid and exaggerated respiration over the apices. In the early part of the following year, she had otorrhœa on the left side, accompanied by deafness, and associated with infra-mammary pain, both of which were relieved by treatment. The month of June 1879 found her complaining of a severe pain of a stitch-like character in her left side, considerable dyspnœa, and of hard cough. At this time there was some suspicion of acute tuberculosis, but as the whole of the symptoms yielded to treatment the diagnosis was never considered positive. Towards the month of November she began to complain of sick headache, and of occasional vomiting. About 2 p.m. every day for some little time she experienced slight rigor, which ended in an intense throbbing headache, localising itself over the occiput, and attended by considerable prostration. From this period onwards the headache became periodic. It would return every second or fourth day, always about two in the afternoon. There was still experienced a degree of minor chill, ending in occipital cephalalgia, for which quinine was given with some benefit to the patient. The tongue remained clean, although there was frequent vomiting and occasionally diarrhœa. The thermometer failed to register any pyrexia at this time.

It was in the end of December that I saw her, in consultation with Mr Hope, when we found her in a state of extreme debility and anæmia, and complaining of intense headache. Careful examination of the chest failed to reveal the presence of disease there. The abdominal and pelvic organs were healthy, so far as could be ascertained. Though the headache was in part considered to be neuralgic or anæmic, seeing the marked relief obtained from quinine, there was every suspicion that there was cerebral disease, but its localisation was a matter of impossibility. The optic discs were examined and found to be normal. At this period of her illness patient frequently played upon the piano, and continued to do so for many weeks afterwards. Application of gold and silver coins a few months later had an almost instantaneous effect on the neuralgic pains in the head and face, and cured a dimness of vision which was considered at the time to be hysterical. There was no disturbance of gait. Motion and sensation remained normal all through. Steady emaciation

continued, and the debility increasing, she died perfectly conscious on the 29th June. For a few days before she died I am informed there was marked dilatation of one pupil and contraction of the other.

On the 30th July 1880, just two years after she first sought medical relief, I had the opportunity of being present at the *post mortem*, which was limited to the head. Rigor mortis was well-developed, and the body was considerably emaciated. On removal of the brain it was noticed that there was a large quantity of a clear watery fluid at the base, part of which seemed to well up from the spinal canal. The cerebellum was removed with difficulty, as it was extremely adherent; all the ventricles of the brain contained a large quantity of fluid. The brain-pulp-membranes and vessels seemed healthy to the naked eye. Nearly the whole of the left cerebellar lobe was occupied by a firm nodule, which was surrounded by a distinct margin separating it completely from the cerebellar tissue. The tumour was easily enucleated. When cut into, it had the appearance of Gruyère cheese, greenish and somewhat yellow. On the whole it was of firm consistence, but in one or two places rather soft and in none diffluent. Occupying its centre was an irregular mass of a jelly-looking material, which was surrounded by enlarged blood-vessels. The membranes were firmly adherent to the surface of the tumour.

On microscopic examination the growth in the cerebellum was found to be tubercular in character; it was composed in the main of numerous small round cells, interspersed through which were numerous fatty points and broken down corpuscles.

In this latter case we have gross lesion of one of the lobes of the cerebellum, with an absence, almost complete, of the ordinary symptoms of such disease. Miss H, all through her illness exhibited none of the reeling gait or muscular inco-ordination which would have been expected from the *post mortem* appearances. How then are we to explain the absence of symptoms in the face of nearly complete destruction of a cerebellar lobe? It is taught by Ferrier that, if each lobe of the cerebellum is symmetrically affected, there is less chance of symptoms arising than if there is lesion of only one. We cannot speak with anything like positiveness of the nature and extent

of the lesion in G.'s case, but from the remark which I have just made, and the knowledge of the fact that the tendency to falling or reeling is usually towards the side on which the lesion is situated, there can be little doubt that the right and probably the middle lobe of his cerebellum are the seat of some diseased process which may be extending in the direction of the bulb. Now, we all know that the symptoms of cerebral disease are not always in proportion to the extent of the lesion, some of the gravest symptoms depending upon the presence of one small tumour, while large foci of softening often exist for months, without giving rise to a single symptom. Is it by an assumption of toleration then, that we are to explain the absence of symptoms in Miss H.'s case? Is it just the case of a very slow growth and simple accommodation to its presence? In the case of the brain we have a dual organ—destruction of a great part of which can take place—especially if plenty of time be given, and none of the higher centres are immediately involved, without giving rise to symptoms. But we have little knowledge that the cerebellum acts in the same way. Each lateral lobe superintends the co-ordination of muscular adjustment on its own side of the body, and consequently disease of that lobe must interfere with the production of that series of well-arranged muscular contractions and relaxations on which maintenance even of the upright position depends. It cannot, therefore, be the case that, on destruction of one lobe of the cerebellum, its function is relegated to the other, as may, and probably does, take place in disease of the brain. In the cerebellum, as in the brain, it is perfectly true that the slower the development of the lesion the less are the chances of symptoms appearing, perhaps not so much from accommodation or toleration to it, as from the fact that time is given for the *acquisition of a power which, consciously exercised, brings about that muscular adaptation which was formerly more of the nature of a series of reflex actions co-ordinated by the cerebellum independently of consciousness.* After this manner, then, we may seek to explain Miss H.'s ability to play the piano up till a few weeks before her death. I have no knowledge of the fact that there was anything like disturbance of the series of co-ordinated movements which such a process involves, and that, to accomplish the act, there had been a reversion to the

primary state of volitional effort. So far as I can ascertain, the accomplishment of the various movements was a matter of comparative ease to her. This, with the patient's ability to walk about in the woods close to her home without exhibiting anything peculiar in her gait, may have been due to the acquisition of that power of which Ferrier speaks—and for which he insists that time must be given[1]—and the existence of which Weir-Mitchell has proved from his experiments on pigeons, for, to use his own words, "notwithstanding extensive destruction of the cerebellum, pigeons recovered steadiness in their movements after many months." Disease of the cerebellum, therefore, does not necessarily imply loss of equilibrium or of muscular co-ordination in any sense of the word, even though, as in Miss H.'s case, it should encroach upon the intracranial space.

[1] Ferrier, *Functions of the Brain*, p. 112, in speaking of the disturbances of equilibrium in cerebellar disease being of an enduring character, says that it is only by a long process of training that volitional acquisition can replace a mechanism essentially independent of consciousness.

SOME OBSERVATIONS ON THE COLOURING MATTER OF JELLY-FISHES. By Professor M'KENDRICK.

WE are all more or less familiar with the splendid colours of some of the *Medusæ* or Jelly-Fishes found in our seas, but I am not aware that any one has made an investigation into the properties of the colouring matter. In the month of September last, I spent some time at the Scottish Zoological Station, then located on the shores of the Cromarty Firth, just opposite Cromarty, and by the kindness of my friends Professor Ewart of Aberdeen, and Mr G. J. Romanes, whose researches on the movements of Jelly-Fishes are well known, I had an opportunity of making some observations.

The specimens examined were the beautiful blue *Cyanea*; *Chrysaora*, distinguished by the patches of brown around the tentacles and the margin of the umbrella and in the long arms; and *Aurelia*, with the crescentic masses of colour round the ovaries.

In the first place, by microscopical examination I ascertained that the colouring matter is not uniformly distributed throughout the protoplasm of these creatures, but that it exists in the form of little irregularly shaped particles in the protoplasm of minute cell-like bodies. The particles or granules were about the $\frac{1}{30,000}$th of an inch in diameter; in the case of *Chrysaora* they were of a yellowish colour, while in *Cyanea* they had a faint tinge of blue. The protoplasm surrounding these granules was colourless. The observations were made with a $\frac{1}{15}$ objective of Ross adapted to a Hartnack microscope, with No. 3 objective and the draw tube out: magnifying power about 1200 diameters.

I then attempted to extract the colouring matter, cutting off the coloured fringes of a large specimen of *Chrysaora*. I placed portions in (*a*) strong caustic potash, (*b*) absolute alcohol), (*c*) sulphuric ether, (*d*) in sea water. In the course of about an hour the portions in strong caustic potash were disintegrated

and broken up into shreds of a dark brown colour, whilst the fluid remained colourless. No effect was produced by absolute alcohol or by ether; but the colour in the fragments immersed in sea water diffused out to a considerable extent in the course of twenty-four hours. The fluid then was of a dark brown colour. Pressure caused no separation of the colouring matter.

I then boiled portions in sea water and in ordinary fresh water, and found that boiling caused the colouring matter to diffuse out quickly. On filtering the fluid, it was found to be acid, and of a dark brown colour. This colour at once disappeared on the addition of strong sulphuric acid; strong nitric and strong hydrochloric acids produced the same effect, but not so quickly as sulphuric acid. Strong caustic potash caused a reddish-brown precipitate, but as the fluid consisted of sea water, at least a portion of this precipitate must have consisted of the hydrated oxides of lime and magnesia in the water. On comparing the effect of adding a solution of caustic potash of the same strength to the same bulk of sea water and of infusion of jelly-fish, the precipitate was decidedly bulkier in the latter case.

As regards *Cyanea* and *Aurelia*, I found that neither pressure, boiling, nor any of the fluids at my command, such as the mineral acids, the alkalies, alcohol, or ether, dissolved out the colouring matter. The only way of obtaining it was to allow fragments of the jelly-fish to macerate in sea water for about thirty-six hours. Then the fluid became of a sky-blue colour when *Cyanea* was used, and slightly pink in the case of *Aurelia*. My next object was to separate the colouring stuff from this fluid. It could not be extracted by alcohol or ether nor by any solution at my disposal, but I ascertained that the fluid thus obtained was slightly acid, and it occurred to me that the colouring matter might be thrown down by an alkali. Experiment showed this to be the case. On adding ammonia to any coloured infusion of jelly-fish, a copious precipitate falls which carries with it the whole of the colouring matter. After filtration the fluid is quite colourless and the colouring matter remains on the filter. Again, the precipitate is readily redissolved by acid, and the colouring matter passes into a

soluble state. It is soluble therefore in an acid medium, but insoluble in an alkaline or neutral medium. Now fresh Jelly-Fishes, so far as I could make out, were quite neutral to test paper. I could not find any alkaline reaction. But in the living Jelly-Fish we can scarcely suppose that the colouring matter exists in the granular form, simply because the medium is alkaline or neutral; all we can state is that the medium is neutral, and the probability is that the colour-stuff is formed in the protoplasm of certain cells just as pigment is formed in the cells of the epidermis of many animals. After the death of the Jelly-Fish, however, the body becomes slightly acid, the protoplasm disintegrates and the colouring matter diffuses out. It is interesting to point out here the analogy to what happens in the case of a muscle. During life a muscle is slightly alkaline or neutral; after death, when rigor sets in, it becomes acid.

I have not had an opportunity of examining the chemical nature of the colouring matter. That is a subject suitable for the chemist and out of my province, but I have pointed out a method by which the colour-stuff can be obtained.

It was a matter of interest to examine the colouring matter with the spectroscope. By means of this instrument, chlorophyll has been discovered in some of the *Protozoa*, in some *Porifera*, in *Hydra viridis*, in the Sea Anemone, *Anthea cereus*, and even in a species of crustacean; various absorption spectra have been studied in certain cœlenterata, echinodermata, worms, insects, and molluscs, whilst in the vertebrata the colouring matter of the blood has received much attention.[1]

I found that infusion of *Chrysaora* gave no distinct absorption bands; but the violet, blue, and a portion of the green were absorbed, the other colours being slightly reduced in intensity. On concentrating the fluid, the red, yellow, and what remained of the green, became very dim; but no bands existed.

With *Cyanea*, however, the case was different. An infusion of this creature containing the colouring matter gave two distinct absorption bands, one in the red and the other in the orange. I also observed these bands very distinctly by placing an uninjured small specimen in a flat glass dish below the microscope.

[1] See Gamgee's *Physiological Chemistry*, vol. i. p. 305.

The only blue colouring matters met with in the animal kingdom that I find any record of is a blue colouring matter obtained from *Stentor cœruleus*, described by Lankester,[1] which gives two absorption bands, nearly the same in position as those observed in *Cyanea;* and a blue matter called *hœmocyanine*, found in the blood of the Octopus, which, however, has no definite absorption bands.

[1] E. Ray Lankester on "Blue Stentorin, the colouring matter of *Stentor cœruleus*" (*Quart. Journ. of Micros. Science*, April 1873.)

THE NERVES OF THE HIND-LIMB OF THE THYLACINE (*Thylacinus Harrisii or Cynocephalus*) AND CUSCUS (*Phalangista maculata*).

By D. J. CUNNINGHAM, M.D., *Senior Demonstrator of Anatomy, University of Edinburgh.*[1]

So much stress is now laid upon "nerve supply" in the determination of "muscle homology," that it becomes a matter of importance to add in every way possible to our knowledge of the comparative anatomy of the nervous system. With this end in view I propose giving an account of the arrangement of the nerves in the hind-limb of the two marsupial animals mentioned above. That the nerve of supply is a most valuable aid in our endeavours to discover the history of a muscle is a fact which no one will deny; but that it is an infallible guide in this respect, as some would have us believe, is a view which is open to many grave objections. In the present paper, however, I do not intend to enter upon this question except in so far as the facts before us bear directly upon it.

LUMBAR PLEXUS.—In both the Thylacine and Cuscus the anterior primary divisions of the lumbar nerves are six in number, but the part which these play in the formation of the lumbar plexus differs in the two animals. In *Thylacinus* the plexus is formed by the first *four* nerves, whilst the *fifth* and *sixth* lumbar nerves join to constitute the *lumbo-sacral cord*. In *Cuscus* the *first* lumbar nerve is quite independent of the plexus, and is expended like the last dorsal in the abdominal wall, whilst the plexus is formed by the union of the 2nd, 3rd, and 4th nerves, and the greater part of the *fifth* nerve. The *lumbo-sacral cord* in this case is composed of the remaining part of the *fifth* and the whole of the *sixth* nerve. In both animals the plexus has the usual looped arrangement.

Branches.—In *Thylacinus* the branches of the plexus come off in the following manner:—(1) *from the* 1*st lumbar nerve* a

[1] This paper is a portion of a memoir which the author is preparing for the Government Reports of the Challenger Expedition. It is published in this *Journal* by permission of the Lords Commissioners of the Treasury.

large branch to the abdominal parietes; (2) *from the loop between the 1st and 2nd,* two twigs to the abdominal parietes; (3) *from the loop between the 2nd and 3rd,* the genito-crural nerve; (4) *from the loop between the 3rd and 4th,* the external cutaneous nerve; (5) *from the 3rd and 4th,* the anterior crural and obturator nerves; (6) *from the 2nd, 3rd, and 4th,* twigs to the psoas.

In the *Cuscus* the branches have the following origin:—(1) *from the 2nd,* a branch to the abdominal parietes; (2) *from the 3rd,* a long nerve to the abdominal wall, and a small twig to the psoas; (3) *from the loop between the 3rd and 4th,* the genito-crural; (4) *from the 3rd and 4th,* the external cutaneous; (5) *from the 3rd, 4th, and 5th,* the anterior crural; (6) *from the 4th and 5th,* the obturator.

If we exclude the 1st lumbar nerve and enumerate the others from the 2nd backwards, there is a striking resemblance between the lumbar plexus in the Cuscus and that in man, both in its mode of formation and in the manner in which the branches take origin.

The three branches which are given off both in Thylacinus and Cuscus to the abdominal parietes correspond to the ilio-inguinal and ilio-hypogastric in man, and they are distributed to the muscles and skin upon the same plan.

The genito-crural proceeds downwards through the psoas parvus to reach the large cremaster, into the deep surface of which it sinks. In the male it is entirely expended in the supply of this muscle, but in the female Thylacine[1] it soon emerged from midst the muscular fibres of the cremaster, and was continued upon the superficial aspect of the muscle through the external abdominal ring, and under cover of the sphincter muscle of the marsupium to the region of the nipples, where it broke up into a series of fine terminal twigs. These, doubtless, were for the supply of the mammary gland, which in the specimen I dissected (evidently a young virgin), could not be detected.

The external cutaneous is distributed to the skin on the outer aspect of the thigh. It pierces the abdominal wall near the

[1] The author has had the opportunity of examining two specimens of Thylacinus, viz., a full-grown male and a young female.

crest of the ilium, and in the Cuscus it was observed to give several fine twigs to the panniculus carnosus.

The Anterior Crural.[1]—In the *Thylacine* this nerve arises in common with the obturator from the 3rd and 4th lumbar nerves, whilst in the *Cuscus* it has an independent origin by two roots from the 3rd, 4th, and 5th nerves. In both it proceeds backwards in the interval between the psoas parvus and magnus, and, entering the thigh, at once breaks up into a large number of muscular and cutaneous branches.

During its course within the abdomen it gives a plentiful supply of twigs to the psoas and iliacus muscles, and in the Cuscus a long slender twig was observed to spring from it, which pierced the abdominal wall to reach the sartorius. In the thigh the *muscular* branches were distributed to the sartorius, the pectineus, and the various parts of the quadriceps extensor muscle. The *cutaneous* branches were the long saphenous nerve and three or four twigs to the skin upon the anterior and inner aspects of the thigh.

The *long saphenous nerve* is a very constant nerve in all mammals, although it varies very considerably in bulk and in its area of distribution. It descends upon the inner aspect of the thigh and leg in company with the vein of the same name, and dispensing numerous twigs to the skin. In the *Thylacine* its terminal twigs are lost in the integuments over the internal ankle. In the *Cuscus*, however, it is continued downwards in front of the inner maleolus for the supply of the skin on the dorsal aspect of the broad opposable hallux. Here it is joined by a twig from a *special nerve* to the hallux (derived from the internal popliteal), and breaks up into three filaments; of these one runs along each margin of the digit, whilst the third proceeds along its middle line. On the dorsum of the foot it effects a communication with the musculo-cutaneous nerve.

A glance at the beautiful figures which accompany Ruge's paper[2] upon "The group of Extensors on the Leg and Foot of

[1] In the ass, in which the lumbar nerves are six in number, the anterior crural nerve springs from the 3rd, 4th, 5th, and 6th nerves; and in the fox, in which the lumbar nerves are seven in number, it takes origin from the 4th, 5th, and 6th (*Swan's Comparative Anatomy of the Nervous System*).

[2] *Morphol. Jahrbuch*, 1879.—Untersuchung über die Extensorengruppe am Unterschenkel und Füsse der Säugethiere von Dr Georg Ruge, Heidelberg.

Mammalia," will show how variable the long saphenous nerve is in respect to its terminal distribution. In the *Mustela foina, Meles vulgaris, Felis domestica, Cercopithecus,* it ends before it reaches the foot; in the *Ornithorhynchus paradoxus, Didelphys virginiana, Nasua socialis, Felis leo, Inuus cynomolgus, Cebus,* and *Orang* it reaches the dorsum of the foot, and supplies filaments to the skin of the hallux. In none of these, however, excepting the Ornithorhynchus, is its area of supply on the dorsum of the foot so wide as in the *Cuscus.*

In a paper by Wm. A. Haswell, M.A., B.Sc., upon the "Anatomy of Birds" (*Pro. Linnean Soc., N.S.W.*, vol. iii.), the author states that the anterior crural, in addition to its branches to the extensors of the thigh, also supplies the glutei and adductor magnus. The adductor brevis and adductor longus, on the other hand, obtain their nerves from the sacral plexus.

The obturator nerve[1] is small in comparision with the corresponding nerve in man. It arises in *Thylacinus* in common with the anterior crural, and in *Cuscus* by two roots from the 4th and 5th lumbar nerves. Its course and distribution is the same in both animals. Quitting the pelvis through the upper part of the thyroid foramen it supplies branches to the obturator externus and the adductors longus and brevis, lying superficial to both, and ends by sinking into the substance of the gracilis. It gives no twigs to the pectineus or adductor magnus, neither does it divide into a superficial and deep division.

SACRAL PLEXUS.—In *Thylacinus* the sacral plexus is apparently formed entirely by the lumbo-sacral cord, which is prolonged into the gluteal region as the great sciatic nerve. No communication could be traced between this great nervous trunk and the first sacral nerve. Before quitting the pelvis it gives origin to (1) the superior gluteal; (2) a special branch to the ecto-gluteus; (3) a special nerve to the hamstring muscles; (4) branches to the pyriformis.

From the 1*st sacral nerve* the pudic and small sciatic nerves take origin.

In the *Cuscus* the arrangement is quite different. The lumbo-sacral cord is joined by the whole of the 1st sacral nerve, and a

[1] In the fox the obturator springs from the 5th and 6th nerves, and in the ass from the 4th, 5th, and 6th (*Swan.*)

small portion of the 2nd sacral nerve, and a large nervous band is thus formed. This divides into two unequal parts, of which the larger is the great sciatic, whilst the smaller gives origin to (1) a special branch to the ecto-gluteus; (2) the small sciatic; (3) the special nerve to the hamstrings.

The *superior gluteal* nerve arises from the lumbo-sacral cord before it is joined by the sacral nerves, and the *pudic* comes from the 2nd sacral nerve.

Nerves to Ecto-gluteus.—The several parts of this muscle (the representatives of the gluteus maximus in man) are supplied differently in the two animals. In *Thylacinus* one large nerve enters the gluteal region through the anterior part of the great sacro-sciatic foramen, and breaks up into branches for the supply of the four constituent parts of the ecto-gluteus. In *Cuscus* this branch is much smaller in size, because the ecto-gluteus also draws twigs from the small sciatic.

Superior Gluteal Nerve.—After emerging from the pelvis through the great sacro-sciatic foramen, this nerve ramifies between the meso-gluteus and endo-gluteus, and supplies filaments to both. In *Cuscus* a long slender twig can be traced downwards to end in the ecto-gluteus, where it folds round the lower margin of the meso-gluteus to become continuous with the endo-gluteus. The fibres to which this twig is distributed undoubtedly represent the tensor fasciæ femoris.

Small Sciatic.—In the *Thylacine* this is a purely cutaneous nerve, whilst in the *Cuscus* it also contains motor fibres which it dispenses to the ecto-gluteus. Emerging from the pelvis through the great sacro-sciatic foramen in front of the pyriformis it makes its entrance into the gluteal region under cover of the meso-gluteus. It soon appears at the posterior border of this muscle, and then proceeds backwards upon the pyriformis and ischio-femoral muscles covered by the ecto-gluteus. Finally dipping under the vertebral origins of the biceps muscle it becomes superficial on the back of the thigh, and is distributed to the skin as low down as the upper part of the leg.

Nerve to Hamstrings.—This is hardly an appropriate name for this nerve, seeing that it has a much wider distribution than to the hamstring muscles. It is a large nerve, composed entirely of motor fibres. It enters the gluteal region through the great sacro-

sciatic foramen, and proceeds backwards upon the endo-gluteus, and under cover of the pyriformis. At the lower border of the latter muscle it gives off a large branch—the representative of the *nerve to the quadratus femoris* in man,—and then continues downwards under the ischio-femoral muscle to the under surface of the biceps muscle. Here it breaks up into a large number of branches for the supply of the biceps and its various accessory vertebral parts, the semitendinosus and the semi-membranosus.

In the *Cuscus, the nerve to the quadratus femoris* sinks into the substance of the gemelli muscles, and is continued backwards through their muscular fibres. Issuing from the midst of the gemellus inferior, it is carried downwards under cover of the quadratus femoris to the adductor magnus. In this course it supplies twigs to the gemelli, quadratus femoris, and probably to the obturatus internus, whilst it ends in the adductor magnus, and constitutes its sole nerve of supply.

In the *Thylacine* the distribution of the *nerve to the quadratus* is precisely similar to that in the Cuscus, but its relations to the gemelli muscles are somewhat different. Each gemellus consists of a superficial and deep part, and the nerve in passing backwards passes between the two portions of the superior muscle, and then under cover of the obturator internus and both portions of the inferior gemellus.

In *Thylacinus* and *Cuscus*, therefore, the adductor magnus is associated by its nervous supply with the quadratus femoris, and it draws branches from neither of its usual sources, viz.:—the great sciatic and the obturator nerves. The advocates for the theory that nerve-supply points infallibly to the homology of a muscle will find this a difficult fact to solve. Of course it might be explained by supposing that the adductor magnus is a compound muscle, consisting of a part belonging to the adductor group, which in this case has fused with the large adductor brevis, and a part derived from the flexor group, which in the present instance is independent, and receives its nerve fibres from the same source but through a different channel, viz., the nerve to the quadratus. That the quadratus femoris is merely the detached upper part of the adductor magnus no one can doubt.

In man the adductor group may be considered to merge in

front with the extensors through the pectineus, and behind with the flexors through the adductor magnus.

Pudic.—This is a small nerve which runs backwards under cover of the pyriformis muscle, and then through the small sciatic notch to the perineum. In the gluteal region of the Thylacine it gives a small twig to the posterior of the two vertebral portions of the biceps, whilst in Cuscus it receives a communicating twig from the nerve to the hamstrings.

Great Sciatic.—The great sciatic enters the gluteal region under cover of the meso-gluteus, and proceeds backwards upon the pyriformis, obturator internus and gemelli, and the ischio-femoral muscle, to the under surface of the biceps. Half-way down the thigh it ends by dividing into three, viz.:—(1) internal popliteal; (2) external popliteal; (3) external saphenous. It gives off no collateral branches.

External Saphenous.—This large nerve proceeds downwards under cover of the biceps to the outer back aspect of the leg, along which it runs to the external maleolus. It is continued behind this bony prominence to the outer margin of the pes, where it ends as the fibular dorsal collateral branch of the little toe. It supplies (*a*) muscular, (*b*) communicating, and (*c*) cutaneous twigs.

The *muscular branches* are different in the two animals. In *Thylacinus* it sends a twig to the lower part of the biceps. In *Cuscus* it gives a branch to the inner head of the gastrocnemius, and another to the fibular part of the vertebral portion of the biceps.

The *communicating branches* are (1) a strongly-marked twig, present in both animals, which passes inwards under cover of the tendo Achilles and the tendon of the plantaris to join the external plantar nerve; (2) in the *Cuscus* a twig to the musculo-cutaneous nerve on the dorsum of the foot.

The *cutaneous twigs* are very numerous, and supply the skin over the outer aspect of the leg and foot.

Internal Popliteal.—This is the largest of the three terminal divisions of the great sciatic. In *Thylacinus* it sends off behind the knee-joint, and between the heads of the gastrocnemius a large number of muscular branches to the superficial and deep muscles on the back of the leg, and then divides into the

external and internal plantar nerves. The gastrocnemius receives two of its muscular branches—one to each of its heads, whilst the poplitus appropriates no less than three. These enter its upper, middle, and lower portions respectively. The second of these proceeds downwards in the interval between the tibialis posticus and flexor longus digitorum, and the third between the tibialis posticus and the flexor longus hallucis.

In the right leg the plantaris was supplied by two twigs from the external plantar nerve.

In *Cuscus* the same muscular branches are given by the internal popliteal, but the nerve ends by dividing into three, viz.:—(1) a nerve to the hallux; (2) internal plantar; (3) external plantar.

The nerve of the hallux is only present in *Cuscus*. It runs downwards alongside the internal plantar nerve between the superficial and deep muscles on the back of the leg. Near the ankle it diverges inwards, leaves the internal plantar, and is distributed to the hallux by a dorsal and a plantar branch. The *dorsal branch* joins the inner of the three terminal twigs of the internal saphenous, and is distributed upon the tibial margin of the digit; the *plantar branch* pierces the inner edge of the abductor hallucis which it supplies, and then forms the inner collateral plantar twig for the hallux. This branch in one limb was joined by a filament from the internal plantar nerve.

Internal Plantar.—The internal plantar nerve runs down the back of the leg between the superficial and deep muscles, and enters the sole by passing behind the internal maleolus.

In *Thylacinus* it now proceeds along the inner margin of the flexor brevis digitorum, and, sinking under cover of the plantar fascia, divides into three digital branches, which are distributed in the following manner:—(1) *the first* goes to the tibial side of the index; (2) *the second*, which is reinforced by a long slender twig from the deep division of the external plantar, bifurcates to supply the adjacent margins of the index and medius; (3) *the third* divides and supplies the contiguous margins of the medius and annularis. From the main trunk several small twigs are given to the flexor brevis digitorum, whilst from the digital nerves no fewer than ten branches are supplied to the plantar pad.

In *Cuscus* the internal plantar at the ankle sends a recurrent branch to the flexor brevis digitorum, and a communicating and reinforcing twig to the plantar portion of the nerve to the hallux. It then enters the sole by passing under cover of the plantar cartilage, and, after sending branches to flexor brevis hallucis, divides into three digital branches, viz.:—(1) *the first* bifurcates to supply the adjacent sides of the hallux and index; (2) *the second* divides for the supply of the contiguous and adherent sides of the index and medius; and (3) *the third* goes to the adjacent sides of the medius and the large annularis, and in addition communicates with the inner digital branch of the external plantar.

External Plantar.—This nerve proceeds down the back of the leg in close company with the internal plantar, and near the heel it is joined by the large reinforcing branch from the external saphenous. The further course of the external plantar differs so much in the two animals that a separate description for each becomes necessary.

In *Thylacinus* it lies close against the os calcis, and entering the sole diverges to the outer margin of the foot under cover of the flexor brevis digitorum. Here it gives twigs to the abductor ossis metatarsi minimi digiti and the long abductor minimi digiti, and then divides into (*a*) a superficial, and (*b*) a deep portion.

The *superficial division* is a purely cutaneous nerve, and almost immediately divides into two digital branches, viz.:—(1) one to the fibular side of the minimus, (2) and a second which bifurcates to supply the adjacent margins of the minimus and annularis. The twig which goes to the tibial side of the minimus is reinforced by a slender filament from the deep division of the external plantar nerve.

The *deep division* of the external plantar turns inwards, and disappearing from view under cover of the great flexor tendon insinuates itself between the plantar or adductor and the intermediate or flexor groups of intrinsic muscles, where it divides into an outer and an inner branch. The *external* branch proceeds downwards, and after giving twigs to the short abductor minimi digiti, the flexor brevis minimi digiti and the fourth dorsal interosseous muscle (*i.e.*, the abductor annularis),

it emerges from under cover of the adductor minimi digiti to the cleft between the minimus and annularis, and joins the tibial digital nerve to the minimus. The *internal* branch is carried transversely across the sole upon the intermediate muscles, and gradually exhausts itself in the supply of the other intrinsic muscles of the foot. It also effects a communication by means of a long slender filament with the digital nerve from the internal plantar to the adjacent margins of the index and medius.

In *Cuscus* the external plantar nerve gains the sole by passing under cover of the ligament which binds the plantar cartilage to the tuber of the os calcis, and immediately divides into a superficial and deep division.

The *superficial branch* proceeds outwards and downwards over the abductors of the minimus, and ends as the fibular plantar nerve of this digit.

The *deep branch* supplies twigs to the three abductors and the opponens of the minimus, and passing under cover of the last muscle it reaches the interval between the plantar and intermediate muscles. Here it divides as in the Thylacine into an outer and inner branch.

The *external branch* emerges from under cover of the adductor minimi digiti, and divides to supply the adjacent sides of the minimus and annularis. The *internal branch* ends by supplying twigs to all the intrinsic muscles, with the exception of (1) abductors and opponens of the minimus; (2) the flexor brevis hallucis, which receives its twigs from the internal plantar; and (3) the abductor hallucis, which is supplied by the nerve to the hallux.

External Popliteal.—In *Thylacinus* this nerve gives off no branches in the thigh, but diverging outwards pierces the outer head of the gastrocnemius, and at once divides into its superficial and deep portions, *i.e.*, the musculo-cutaneous and anterior tibial.

The *musculo-cutaneous*, unlike the corresponding nerve in man, is intended for the supply of skin alone. It proceeds downwards upon the anterior aspect of the leg, dispensing filaments as it goes, and ultimately it reaches the dorsum of the foot where it ends in four branches, which have the following distribution:—

(1) the first (counting from the inner margin of the foot) constitutes the tibial branch upon the dorsal aspect of the index; (2) the second joins the fibular dorsal branch of the index, which is derived from the anterior tibial; (3) the third joins the fibular dorsal branch of the medius, which also comes from the anterior tibial; (4) whilst the fourth bifurcates to supply the adjacent margins of the minimus and annularis.

The *anterior tibial nerve* proceeds forwards between the two heads of the peroneus longus, and then pierces the peroneus brevis and extensor communis digitorum to reach the interval between it and the tibialis anticus. It is now continued downwards upon the interosseous membrane, and, passing under cover of the upper annular ligament, it reaches the dorsum of the foot, where it ends by dividing into two dorsal digital branches. These are distributed thus:—(1) the first divides to supply the adjacent sides of the index and medius, whilst (2) the second bifurcates to end upon the contiguous margins of the medius and annularis.

Muscular Branches.—Between the heads of the peroneous longus the anterior tibial gives off a great number of muscular branches which go to the two heads of the peroneus longus, the peroneus brevis, the extensor brevis minimi digiti upon which the nerve lies, the common extensor, and the tibialis anticus. A long slender twig also proceeds downwards to supply the two lower portions of the extensor brevis. Whilst the nerve lies between the tibialis anticus and the common extensor it gives additional twigs to the inner part of the latter, which might be considered as an indication that the absent extensor longus hallucis is fused with the extensor communis digitorum.

In the *Cuscus* the external popliteal does not pierce the outer head of the gastrocnemius. At the head of the fibula it divides into the musculo-cutaneous and anterior tibial.

The *musculo-cutaneous*, in passing down the leg, supplies a few twigs to the biceps, under cover of which it runs. No branches, however, are given to the peroneal muscles. On the dorsum of the foot it breaks up into four branches which supply dorsal digital twigs to both sides of all the toes, with the exception of the hallux and the outer margin of the minimus.

The *anterior tibial* in the Cuscus is a purely motor nerve, and

differs from that in the Thylacine by ending on the dorsum of the foot by supplying the extensor brevis of the index and medius, which in this animal has wandered downwards so as to lie upon the dorsum of the foot. In the front of the leg the nerve lies between the extensor longus hallucis and the tibialis anticus.

The comparative anatomy of the external popliteal nerve has recently received special attention by Dr Georg Ruge in his elaborate memoir upon the extensor muscles of the leg and foot in Mammalia. He examined three marsupials, viz., the *Didelphys virginiana*, the *Didelphys cancrivora*, and the *Dasyurus hallucinatus*. In all these the general arrangement of the nerve was very similar to that which I have described as existing in the Thylacine and Cuscus. There seems to be, however, a great variation in the relative distribution of the musclo-cutaneous and anterior tibial to the skin on the dorsum of the foot. In Dasyurus as in Cuscus the anterior tibial is purely motor, and although it reaches the dorsum of the foot it gives no branches to the integument. In both specimens of Didelphys as in the Thylacine, the anterior tibial combines a large proportion of sensory fibres with its motor fibres. Thus in *Didelphys virginiana* it supplies the adjacent sides of the index and medius, and also the fibular side of the hallux, whilst in *Didelphys cancrivora* it sends twigs to both sides of the index and the tibial side of the medius, and this combination of fibres in the anterior tibial, as Ruge shows, seems to be the more usual disposition throughout Mammalia generally. In some animals, indeed (as for instance the Ateles), the anterior tibial appears almost to supplant the musculo-cutaneous as the nerve of supply to the dorsal aspect of the digits.

Ruge is apparently a firm believer on the invariable and immutable relationship between "nerve supply" and "muscle homology." Even in the extensor group of muscles in the front of the leg, however, he discovers some facts which are rather hard to explain in the light of this theory. Thus in the *Ornithorhynchus paradoxus* he finds the tibialis anticus and the inner portion of the extensor longus hallucis supplied by a branch from the anterior crural, which is prolonged downwards to its destination over the external condyle of the femur. He is therefore obliged to assume that "the internal part of the extensor longus hallucis

and the tibialis anticus are not homologous to the similarly named muscles" in other animals, but "belong rather to the extensor group of the thigh." He believes that these fibres, which are supplied by the anterior crural, are gradually abolished, and that their place is taken by the external muscles of the lower leg. The leap, however, between the Monotremata and Marsupialia, in which both muscles are well developed and entirely supplied by the anterior tibial nerve, is too great for us to give credence to this supposition.

In the nervous arrangements in the hind-limb of the Thylacine and Cuscus there are facts which also require explanation if we are to accept this view. Thus the biceps and its accessory parts receives twigs from (1) the pudic; (2) the nerve to the hamstrings; (3) the external saphenous; (4) the musculo-cutaneous; the adductor magnus is entirely supplied by the nerve to the quadratus femoris; and the inner head of the gastrocnemius in the Cuscus receives a twig from the external saphenous. If the source in the spinal cord from which the nerve fibres are derived is invariably the same, it is at least certain that the nerve-strands through which the fibres reach the muscle are often very different.

PULSE DICROTISM. By WM. JAS. FLEMING, M.D.

Thesis for the Degree of Doctor of Medicine, presented to the University of Glasgow, October 1879. (*Commended.*)

DESPITE the enormous amount of labour and thought bestowed upon attempts to explain "pulse dicrotism," much doubt still exists as to the manner of its causation.

It is well known that waves can be produced in elastic tubes exactly similar to those existing in the arteries, and practically identical tracings can be obtained from both.

It seemed to the author that by taking tracings from india-rubber tubes under many different sets of conditions, without at first attempting to prove anything, facts might be elicited which would suggest a solution of the problem.

METHODS EMPLOYED.

To represent the heart:—1st. Burdon Sanderson's schema[1] with a head of water of about 1½ metres (S in fig.).

2d. A simple head of water of about the same height.

3d. A Higginson's syringe worked by the hand.

For artery I used various lengths of extremely thin india-rubber tube made specially for the purpose; internal diameter of lumen, 5 millimetres.

The amount of peripheral resistance was regulated by (*a*), partial closure of exit tube, (*b*) elevation or depression of end of tube, and (*c*) by causing the water to escape into a vessel by an aperture near the bottom, and to overflow by an opening some inches higher, this vessel being raised and lowered (V in fig.).

By this last device a resistance closely analogous to the mass of blood in the capillaries is obtained, and can easily be altered in amount by elevation and depression of the vessel. Indeed, this simple arrangement seems much superior to constricting the aperture of exit as is usually done.

The movements of the artery were recorded by means of my tambour sphygmograph (T in fig.), described in the *Journal of*

[1] See *Laboratory Handbook*, p. 221, plate lxxxvi. fig. 211.

Anatomy and Physiology, vol. xii. p. 144. This is simply a tambour with a wire fixed to its centre, perpendicular to the membrane, armed at the end with a button for application to the artery or tube. Above the button can be placed split weights. From this the motion is communicated to the recording tambour, and traced on the cylinder as usual. Very numerous modifications of these methods were employed, and a few of

P, Pressure barrel; S, Schema; T. Sphygmograph; C, Cylinder; V, Resistance vessel; M, Manometer; *a*, Auriculo-ventricular valve of schema; *b*, Aortic valve of schema; *c*, Artery; K, Tube from P.

them are described, when required, in the subsequent portions of this paper.

The investigation thus conducted first led to a refutation of the different theories held by physiologists. These we may now advantageously enumerate.

VIEWS AT PRESENT HELD.

It may probably be taken for proved that the dicrotic notch is produced by a wave proceeding from the centre to the periphery, as it has been abundantly shown that it occurs later the further from the heart the observation is made. All recent authors have discarded the idea of a reflexion from the periphery.

There remain, then, five theories of which we require to take account:—

1. Vibration caused by closure of aortic valve.
2. Vibration of the walls of the artery (M^{c}Vail).
3. A reflexion from aortic valves of a reflux of blood produced by the resistance of the blood already in the more peripheral parts of the circulation (Galabin).
4. A second contraction of the root of the aorta following a distension produced by a rebound from the great arteries in front (Burdon Sanderson).
5. An active contraction behind each pulse wave—a vermicular contraction (C. S. Roy).

Arguments against the views at present held.

First Theory.—Vibration caused by Closure of Aortic Valves.

The schema was arranged in the ordinary way, but immediately beyond it a T-tube was introduced and the free leg connected with a mercurial manometer (M in fig.) of considerable calibre. The proximal end was thus put in communication with the part of the experimental tube representing the aorta, and was filled with water above the mercury. The distal was closed, air being above the mercury. The sphygmograph was applied about 1 metre from the schema. On working the instrument slowly, tracing 2 was obtained. In this the dicrotic rise is well marked, and also the vibration caused by the closure of the aortic valve occurring *long after* (No. 2 *a*). The closure of the aortic valves cannot then be the cause of the secondary wave, although, in accordance with the theory to be advanced, it will necessarily occur in the healthy heart almost synchronously with the origin at these valves of the wave. Dr M'Vail[1] has shown that dicrotism may be produced by a simple depression of a piston, and argues from this, that the aortic valves do not produce the wave, but it seems evident that the cessation of the descent of the piston most perfectly represents the closure of the valves, and that, therefore, his experiment rather goes to prove the opposite of the conclusion he draws from it.

In the tracing (2) the dicrotic notch must have been produced

[1] *Glasgow Medical Journal*, 1874, p. 1.

independently of any action of the valve, representing the aortic, as from the construction of the schema, the opening of this valve and the closure of the auriculo-ventricular are simultaneous, and coincide with the beginning of the upstroke, so that at the moment of the secondary rise in trace 2 the instrument was at rest; the aortic valve open, the auriculo-ventricular shut.

Second Theory.—Vibration of the Walls of the Artery.

This theory, as far as I can trace, was first distinctly advanced by Dr M'Vail in the paper just referred to. It seems inherently improbable from the *damping* effect the surrounding tissues must have upon the vessel walls. An artery differs from an ordinary experimental elastic tube in being tightly packed among the tissues, not surrounded by air, and any vibration of its walls would be damped, if not extinguished, by the investing structures.

To show that this is the case the following method was resorted to. The button of the sphygmograph was *cemented* to the wall of the tube, no weight being put upon it, and the membrane of the tambour being very slack. Next, the tube and sphygmograph button were immersed in mercury to such a depth that only the wire, a thin one, emerged from the liquid. By this arrangement the chances of the momentum of the instrument affecting the trace are practically eliminated. And this disposition of the apparatus must have closely simulated the condition of the vessel packed amongst the tissues. The simple tube, opened and closed with the finger, was employed, the manometer being introduced as above described. The tracing obtained is figured in No. 4, showing that a marked dicrotic rise may exist under circumstances which preclude the possibility of vibration of the wall of the vessel itself.

This experiment seems also conclusive that the theory attributing the notch to vibration of the sphygmograph is untenable, but this has practically already been disproved.

Third Theory.—Reflexion of a Wave produced by Peripheral Resistance (Galabin).

This theory is consistent with my observations, in so far as it attributes the phenomenon to a wave reflected from the cardiac

end of the aorta, but their explanation of the method by which the original wave is caused to travel towards the heart does not seem satisfactory. It must be admitted that a closure of the cardiac end of the aorta must exist, or the circulation could not go on, and this closure may either be as in health the shutting of the aortic valves or as in mitral insufficiency the closed or even partially filled ventricle. But the peripheral resistance is more yielding than this, and it is difficult to conceive how it could produce a reflected wave of sufficient intensity to cause, after being again reflected from the cardiac end of the aorta a rise of the extent of the dicrotic notch. Besides, as will be dwelt upon in the sequel, the dicrotic notch increases with diminution of peripheral resistance, while, by this theory, we would expect it to increase.

Fourth Theory.—A second Contraction of Aorta after distension produced by rebound from Peripheral Vessels (Burdon Sanderson).

The objections to Dr Galabin's theory are equally applicable to this. Indeed, practically, if such a rebound exists it must dilate the aorta, or at least arrest its contraction as well as be reflected from the cardiac end.

Fifth Theory.—A Vermicular Contraction of the Artery behind each Pulse Wave (C. S. Roy).

Dr Roy's revived theory of a peristaltic contraction of the vessels seems at once negatived by the ease with which a dicrotic rise can be produced in elastic tubes which he surely cannot consider capable of an " active vermicular contraction." But besides, in tracing 9, we have a curve evidently representing the dicrotic notch, and in the arrangement which produced this tracing, the whole experimental tube, from the point at which the closure representing the valve was made to the end, was constructed of glass tubing united by the shortest possible pieces of india-rubber tube, except at the one place where the flexible pipe was about 2 inches long, to permit the application of the sphygmograph.

In this experiment there was only about 3 inches of the

tube in all india-rubber, and yet we have two very marked notches, probably the pre-dicrotic and dicrotic.

EXPLANATION OFFERED.

All the theories above enumerated having failed to account for the phenomena, a consideration of a great mass of tracings, and of the mechanical conditions involved, led the author to attribute the secondary rise to *a rebound from the cardiac end of the aorta of the wave produced by the aortic contraction itself.* To make this clearer, let us consider what happens if an elastic ball such as a Higginson's syringe be compressed. We have here the fluid it contains driven equally in both directions back and forward, so that two streams of fluid are produced travelling in opposite directions; and if there were no valves or other obstruction equal quantities would flow from either exit tube, but, with a valve preventing reflux through the influx tube, we have the fluid which would have passed out by it in the absence of any obstruction *rebounding*, and the whole fluid passing out by the unobstructed orifice. The aorta is directly comparable to the ball of the syringe, and, in speaking of the aorta in this connection, we may probably include the first part of the great vessels arising from it. The ventricular systole distends them to the utmost limit, the greatest distension being just before its cessation. This systole ceases more or less abruptly, and the aorta instantly begins to contract upon its contents, not by a species of peristaltic action, but simultaneously, or nearly so, in its whole length. The blood is driven back upon the aortic valves with the same force as it is driven forward into the circulation. This backward wave is universally admitted to close these valves, and this is probably its first action, but, having effected this, it must be reflected from them, and it is this reflexion, which, in the author's opinion, passing down the vessels, or rather acting on the mass of blood they contain, produces the dicrotic wave. If this is the true explanation we must consider how it can be demonstrated, and how it explains the conditions found to influence dicrotism.

Experimental Demonstration.

If a quantity of fluid be injected into the part of the experi-

mental tube representing the aorta, the injection beginning at the moment when distension ceases, an increase in the dicrotic wave should be produced—an increase if the dicrotic notch is present without the injection, a production if previously absent.

Many methods of producing this influx of fluid into the artificial aorta at the exact time were tried; amongst others (*a*) a manometer introduced as described, and, as shown in the drawing (M); (*b*) a vertical tube of considerable length substituted for the manometer, and closed at the end, the upper portion containing air; (*c*) a dilatation (a Higginson syringe without valves), compressed by a flat board heavily loaded.

By these devices the wave has been uniformly increased, or, if absent, produced. Of the first of these, which gave the most marked results, we have in the appended tracings the following examples.

2 and 7. The manometer in } other conditions the same.
3 „ 6. The mauometer out } other conditions the same.
4. The manometer in—sphygmograph glued to tube and immersed in mercury.
5. The manometer out—otherwise same as 4.

In these the effect of the injection of fluid produced by the manometer in increasing the dicrotic notch is well marked, and it is worth notice that the secondary vibrations which are so apt to occur in experiments with elastic tubes, are wanting when the conditions favouring vibrations in the tube, are removed by its immersion in mercury, and a state of matters closely analogous to that existing in the arteries is produced.

In 8 and 9 we have tracings taken from an arrangement of glass tubes connected by the shortest possible elastic joints, except at one point where about 2 inches of india-rubber tube was interpolated to permit of the application of the sphygmograph; otherwise the arrangement is the same as with the elastic tubing in (9), the manometer being used. In these curves the dicrotic notch is represented at (*a*), and the enormous increase of this curve when the manometer is introduced, compared with the same curve in 8 without it, seems only explicable by the theory above propounded.

Indeed, if tracing 8 be compared with tracing 10, in which the button of the sphygmograph was rapidly jerked up by a tap of the finger on a lever placed below it, and allowed at once to fall smartly, it will be seen that a similar curve, due to the rebound of the sphygmograph weights is produced; and this is evidently the cause of the curve (*b*) in tracings 8 and 9. The manometer, however, in 9 has produced a very marked curve (*a*) which corresponds in every way to the dicrotic notch in an ordinary tracing.

The effect of the introduction of the manometer is well seen by comparing 2 and 3, in which Burdon Sanderson's schema was used, a long pause being made between the opening of auricular ventricular valve and the closure of the aortic. In No. 2 the manometer was employed, in 3 it was shut off. The other points brought out by this trace are dwelt upon above. In Nos. 4 and 5 the sphygmograph and tube were in mercury, and the button of the sphygmograph was *cemented to the tube.* In 4 the manometer was employed, in 5 it was left out, the other conditions being the same. The effect of this, in suppressing all subsidiary vibrations, and in 4, where the manometer is in action, producing a close resemblance to the down stroke of a normal pulse, is most marked.

The two tracings, 4 and 5, were produced by simply opening and closing the tube with the finger.

From these experiments then, it is plain, the injection of fluid into the part of the tube representing the aorta at the moment succeeding its utmost distention, produces a wave in all respects exactly corresponding to the dicrotic. This injection of fluid closely simulates the effect of the contraction of the aorta, acting like it in two directions; the one half aiding the centrifugal flow of the fluid, the other being projected against the aortic valve, and by its rebound from this producing a second or dicrotic wave.

If this is the case, a tracing taken from the artificial aorta, nearer the heart than the point at which the injection is made, should show first a rise produced by the fluid flowing towards the heart, immediately followed by a second rise due to its rebound, and this will be seen to be the case on examination of the trace 11 (*a*), which was obtained on the central side of

the expansion of the aorta, compressed by weights as previously described; and what is more, the second curve produced by this reflux, should precede in time the dicrotic notch, in the artery by an amount varying with the length of tube intervening. In No. 11 we have two synchronous tracings, taken the one (*a*) above, the one (*b*) some distance below the distention, and the corresponding points in each marked in the usual way. It will be seen that the second or reflux wave in (*a*) precedes by a distinct interval the dicrotic notch in (*b*), and in tracing 12, in which the sphygmograph giving the tracing (*b*) was placed much nearer the expansion, it is plain that this interval is diminished. This goes far to show that it is this rebounding wave which produces the notch. Indeed, it has been shown by Chaveau and Marey, that such a centripetal wave occurs just at this period in the carotid of the horse.

Applicability of Theory to Physiological Variations.

Let us now consider how this theory explains the alterations in the intensity of dicrotism under different conditions. These conditions are very explicitly laid down by Marey, and may be thus summed up:—

Conditions increasing the dicrotic wave.

(*a*.) Fast pulse.
(*b*.) Elastic vessels.
(*c*.) Feeble tension in vessels.
(*d*.) Small quantity of fluid injected at each ventricular systole.

The reverse of these conditions produces decrease of the wave.

The reason why all these increase the dicrotic notch appears to be one and the same, viz., that *the amount of a fluid rebound depends more on the velocity of the impact than upon the mass projected.*

In (*a*) and (*d*), which are practically two ways of stating the same thing, we have a short sharp distension of the aorta followed by sudden cessation of the expanding force. As the contractile force of elastic tissue is greater the less the amount of previous extension, we will have the fluid driven back faster

and a greater rebound produced despite the fact that the mass of fluid is less. In (*b*) we find a strong confirmation of the explanation advanced, the greater elasticity of the aorta necessarily producing a more powerful reflux wave.

In (*c*), which is perhaps the most important from a clinical point of view, we have to deal with a diminished tension in the aorta, but probably not with a proportionally reduced expansion, by the ventricular contraction, so that the aorta having to contract against less resistance will do so more rapidly and forcibly, and thus produce a rapid centripetal wave.

Application to Pathological Variations.

It remains to us to consider how pathological conditions influence the wave. The chief of these are :—

(*a.*) Aneurisms of the aorta.
(*b.*) Obstructions of the aortic orifice.
(*c.*) Incompetency of aortic valves.
(*d.*) Rigidity of arteries.

(*a.*) In aortic aneurisms two conditions may be more or less distinctly present. Either we may have what is practically a dilatation of the aorta, or a sac opening off it, by a comparatively narrow orifice. Upon the above theory we would expect these conditions to produce opposite effects upon the dicrotic wave, the first diminishing, the second increasing it. M. Marey has shown [1] that, in the first case, we find diminution, if not complete extinction, of the wave. In the second case a marked increase, as we would expect, is found [2] both in a patient with this affection and also in an imitation of the disease on the schema.

(*b.*) In aortic obstruction the marked absence of dicrotism is also confirmatory of the views advanced.[3] Here the comparative slowness of the entrance of the blood into the aorta permits of its discharge into the peripheral circulation, without a distension of the aorta sufficient to give rise to a contraction of great enough extent to produce a rebound.

[1] *Circulation du Sang*, p. 461. [2] Marey, *op. cit.* p. 458.
[3] Marey, *op. cit.* p. 504.

(*c*.) In incompetency of the valves, on the other hand, we sometimes have marked dicrotism,[1] but, as Marey points out, this is accompanied by low tension, and a very sudden and high rise of the upstroke, showing a great and sudden distension of the aorta, conditions which we have seen are peculiarly favourable to the production of the wave according to the explanation now offered.

(*d*.) In rigid arteries, on the other hand, we have suppression of the wave; this, however, we would naturally expect on almost any theory.

Dr Galabin failed to obtain a marked dicrotic trace from the aorta itself, but this, as well as some other observations by various authors, is probably explained by the consideration that, for the same amount of fluid injected into a given length of vessel the excursion of the wall of the vessel will be less the greater its sectional area, so that a wave of fluid capable of producing a marked distension of the radial might be quite inadequate to give a motion of the aortic wall of sufficient extent to record itself.

CONCLUSIONS.

To sum up, it has been shown that on general physiological grounds it must be admitted that the contraction of the aorta immediately succeeding its expansion by the ventricular systole must produce a current of blood flowing towards the heart, as well as one flowing towards the periphery, and that this current, impinging on the aortic valves or their substitute, must be reflected.

A simulation of this state of matters in a simple schema produces a dicrotic notch which without it is wanting. Therefore *this reflux of blood towards the heart produced by the aortic contraction and reflected from the cardiac end of the aorta produces the dicrotic notch.* This is borne out by *experiment*, showing that by a simulation of these conditions the dicrotic wave can be produced, when all other things being equal it is absent.

In *Physiology* and *Pathology* it explains how the variations in intensity of the dicrotic wave can be satisfactorily accounted for

[1] Marey. *op. cit.* p. 510.

by the theory advanced. In conclusion, it may be stated that, although typical tracings have been selected, numerous others were taken bearing out equally well the propositions advanced.

Postscript.—Since writing the above, I find that Dr Mahomed has advanced in the pages of the *Medical Times and Gazette* for Nov. 1st, 1873, a theory of dicrotism somewhat similar to the one just propounded, but, as far as I can understand from the very short account there given of it, while asserting that "the elastic recoil of the aorta must be admitted as the primary origin of the dicrotic wave," he seems to consider that this acts towards the periphery and not by a reflected wave. Tracings 10 and 11 seem to show that this is not the explanation.

Physiological Laboratory,
Glasgow Royal Infirmary School of Medicine, 1879.

Explanation of Tracings.

1. Curve produced by opening and closing with the finger and thumb an elastic tube arranged so as to give a head of water of about 1½ metres above the point of closure, and to extend 2 metres beyond in a nearly horizontal line, ending in a smaller exit tube. The sphygmograph was placed about a metre from the point where the tube was compressed.

2. Burdon Sanderson's schema, but a mercurial manometer of about the same diameter as the elastic tube connected by a T piece with the portion of tube representing the aorta, 6 inches from the part of the apparatus which imitates the aortic valve. The distal end of the manometer was closed (see figure).

3. Same, but manometer shut out by a strong clip.

4. Simple tube as in No. 1, manometer added as in 2, sphygmograph and a portion of elastic tube immersed in mercury, resistance by mass of water in a vessel (V in fig.).

5. Same—manometer shut off.

6. Same conditions a 2 and 3, resistance considerable—manometer off.

7. The same as 6—manometer in action.

8. Tubing beyond valve all glass, except short junctions and 2 inches close to manometer, on which sphygmograph placed, resistance as in 4—manometer shut off.

9. Same—manometer on.

10. Sphygmograph on partially filled tube moved by taps on a lever placed below the support for the weights.

11. Synchronous tracing from each side of an india-rubber expansion (a Higginson's syringe without valves) introduced into the continuity of the simple tube, an ordinary Higginson's syringe worked by the hand being used to represent the ventricle, with the resistance reduced by placing the tub of water (V in fig.) into which the exit tube was led below the level of the table on which the artificial vessel lay, and compressing the expanded part by a weight of 2 lbs. placed on the end of a flat lever, giving a pressure about double that of the actual weight used. The sphygmograph giving tracing (*a*), being between the pump and the expansion. The upper tracing (*b*) being taken from a point at a considerable distance from the expansion.

12. The same, but trace (*b*) taken near the expansion.

Anatomical Notices.

ON SOME ANATOMICAL VARIATIONS. By Francis J. Shepherd, M.D., C.M., M.R.C.S. Eng., *Demonstrator of Anatomy, M'Gill University, Montreal.*

The following are some of the more interesting variations which were observed in the dissecting-room of the M'Gill University during the Winter and Summer Sessions of 1879–80, and which I think worthy of being recorded :—

Dorso-Lumbar Vertebra.—This occurred in a male subject. There was the usual number of cervical and dorsal vertebræ, then came this extra one, and it was followed by the usual number of lumbar vertebræ. This supernumerary one partook of the characters of both a lumbar and a dorsal vertebra; on the right side it had a small rib 1¾ inches long, and ¼ of an inch broad, articulating with it. This rib had a downward direction, and was grooved on its under surface. It was bound down by ligaments to the whole length of a transverse process ⅓ of an inch long. The rib was not freely moveable.

On the left side there was a transverse process which looked very like a rudimentary rib, and had the downward direction of a rib. It was the same length as the transverse process of the first lumbar vertebra, but much narrower, and rounded. At its root it was nearly ½ an inch broad. As it proceeded outwards, it became much smaller, being only ⅛th of an inch broad, and it ended in a bulbous extremity. The whole vertebra was of the usual size of a lower dorsal. In this subject the abdominal aorta divided opposite the third lumbar.

Eight Ribs articulating with the Sternum, three with the first piece.—In a male subject aged forty years, it was noticed, on preparing it for dissection, that the chest was of unusual length. On examination, this was found to be due to the fact that the first piece of the sternum was twice as long as normal, and had the cartilages of the first three ribs articulating with it. With the second piece the next five ribs articulated, thus making in all eight ribs articulating with the sternum. The ensiform cartilage was completely ossified, and articulated with the gladiolus by means of cartilage. The inner halves of the cartilages of the first ribs were also completely ossified. The second costal cartilage articulated with the first piece of the sternum about its middle, and the third cartilage at the junction of the first and second pieces.

Length of sternum, exclusive of ensiform cartilage,	7½	inches.
,, manubrium,	3½	,,
,, gladiolus,	4	,,
,, ensiform cartilage,	1½	,,

This variety of sternum is rather unusual, and is the first and only case in which I have seen such an arrangement of the ribs, although since I have had this preparation, I have examined several hundred chests in hospital, and have seen none with three ribs articulating with the first piece of the sternum. That this is a rare variety of the sternum, is shown by the fact that text-books on surface marking always give as a guide to the second rib the junction of the first and second piece of the sternum. Professor Humphry, in his valuable work on the "Human Skeleton," refers to this abnormality as being mentioned in Meckel's *Archiv*, iv. 480. This is the only reference to it that I can find.

Unusual Sesamoid Bone.—In left foot of a muscular man, a railway brakesman, a sesamoid bone was found in the tendon of the flexor longus hallucis muscle, as it passed over the os calcis and astragalus. This bone was completely ossified and about the diameter of a sixpence; on its under surface were two facets for articulating with the os calcis and astragalus at this junction. Whether the man's occupation had anything to do with the development of this bone I do not know, but he certainly used his left foot in applying the brakes.

Varieties of the Pterygoideus Proprius Muscle.—A form of the pterygoideus proprius muscle was seen several times. In all the cases in which it existed, the upper head of the external pterygoid was very small, or wanting altogether. Although this muscle has not often been described, it occurs more frequently than is generally supposed, but is nearly always destroyed or mutilated by the student in removing part of the ramus of the lower jaw. I have seen it several times during the last five years, but it was always in such a mutilated condition that I never ventured to describe it. During last winter, I saw three examples of the pterygoideus proprius muscle, or rather a variety of it; one of these, which occurred in a young Indian girl, I carefully dissected out, and have now preserved in the Museum of the College. The following is a brief description of this specimen. "Superficially it is continuous at its origin with the under surface of the temporal muscle, but its chief and deep origin is from the pterygoid ridge of the sphenoid, and part of the great wing, in common with, but superficial to, the small upper head of the external pterygoid. From this origin the muscle curves downwards and towards the buccinator muscle, having along its inner border a well-defined tendon, and is inserted by a broad aponeurosis into the alveolar process of the superior maxilla, opposite the molar teeth and into the pterygo-maxillary ligament. Some of its muscular fibres also became blended with the buccinator muscle. In its course it crosses the external and internal pterygoid muscles. The muscle is somewhat fan-shaped, $\frac{3}{4}$ of an inch broad, and 2 inches long; from its under surface, in addition to the above attachments, it sends a small muscular fascicular below the internal pterygoid to be inserted into the tip of the hamular process of the internal pterygoid plate." Its action was evidently to assist in closing the jaws.

In the second case the abnormal muscle seemed chiefly to be con-

tinuous with the under surface of the temporal, a few fibres only arising from the pterygoid ridge. The slip was of small size, and was inserted altogether into the pterygo-maxillary ligament.

In the third case, the slip was of larger size, and arose from the great wing of the sphenoid and pterygoid ridge; it passed down and was inserted into the posterior part of the alveolar process of the upper jaw, and sent a thin muscular slip down over the internal pterygoid to be inserted into the inferior maxilla near its angle.

Rectus Thoracis.—This occurred on the left side of a male subject. It arose by a thin tendon from the anterior surface of the fourth rib, just external to the origin of the serratus magnus; from this origin it passed directly up over the third rib and under the pectoralis minor muscle, receiving some tendinous slips from the intercostal muscles, it then went over the second rib, and was inserted into the first rib immediately external to its junction with the costal cartilage. This muscle was $1\frac{1}{4}$ inch broad at its origin, and $\frac{1}{2}$ an inch broad at its insertion. In the same subject and on the same side the *Scalenus posticus* was attached to the third rib by a strong muscular slip.

Chondro Scapular.—This muscle occurred twice, in both cases on the right side of a male subject.

Case 1. The muscle arose from the upper border of the scapula near the notch, and also from the ligament over the notch, with the posterior belly of the omo-hyoid by a fleshy origin, it then passed forwards under the clavicle and subclavius muscle, and over the axillary vessels to be inserted into the costal cartilage of the first rib by a round tendon.

Case 2. In this case the origin was from the coracoid process, posterior to the insertion of the pectoralis minor muscle; it passed from this origin, which was broad and fleshy, along the lower border of the clavicle to be inserted, as in Case 1, by a round tendon into the costal cartilage of the first rib. It blended somewhat with the costo-coracoid membrane. The subject being very thin, this muscle was noticed before the integument was removed, on account of its standing out so prominently. On both sides in this subject the subclavius muscle was attached along the under surface of the clavicle from the sterno-clavicular articulation to the coraco-clavicular ligament, and also on the left side had an attachment to the root of the caracoid process. This latter would seem to be a fusion between the subclavius and chondro-scapular muscle.

Abnormal Lumbricalis.—In the left hand of a muscular male subject, the innermost lumbricalis arose by a long thin tendon from the raphé between the tendons of the sublimis digitorum going to the index and ring fingers; this tendon passed under the annular ligament, where it became muscular; it then passed beneath the superficial and deep flexor tendons, and wound round to the radial side of the little finger, where it was inserted as usual. The fleshy part of this lumbricalis was double the length of any of the others.

Splenius Colli.—In a male subject, the right splenius colli muscle consisted simply of two fasciculi, the upper one of which was blended

with the splenius capitis, and was inserted by a round tendon into the posterior surface of the transverse process of the atlas; the lower fasciculus arose from the fourth and fifth dorsal spines, passed up, received a small muscular slip from the fourth rib near its angle, and was inserted into the posterior tubercle of the transverse process of the third cervical vertebra. It also sent a broad tendinous attachment to the under surface of the levator anguli scapulæ.

Transversus Perinei.—On both sides in the same subject, this muscle was irregular. On the left side it had a very broad origin from the tuberosity of the ischium, and after continuing inwards for about ⅛th of an inch, divided into two parts; the *superior* (1½ inch long, and ¼ inch broad) passed upwards and inwards to become blended, partly with the fibres of the accelerator urinæ muscle which surround the bulb, and partly with those fibres which encircle the penis. The *inferior* part was broad and fan-shaped, the transverse fibres being inserted into the tendinous point of the perineum, the greater part of the muscle spreading out and blending with the levator ani. On the right side the erector penis and transverse muscles at their origin could not be separated; they passed upwards together as one muscle, and as this muscle advanced inwards it spread out widely and blended with the accelerator urinæ. I have several times seen the transversus perinei muscle of a fan-shape, a few only of its fibres being inserted into the tendinous point of the perineum, the rest being lost in the accelerator muscle.

Unusual variety of Mylo-hyoid Nerve.—On both sides of the same subject, this nerve, after giving branches to the anterior belly of the digastric and mylo-hyoid muscle, pierced the latter and joined the lingual nerve, thence its fibres were traced to the lingualis muscle, which it in great part supplied. The chorda tympani nerve was very minute, and sent only a very small filament to the lingualis.

Thyroid Cartilage pierced for passage of the superior Laryngeal Nerve and Artery—In one subject on both sides, and in another on the right side only, the thyroid cartilage was pierced by a large foramen the size of a goose quill, through which passed the superior laryngeal nerve and artery. This foramen was situated in the great wing of the cartilage, ¼ of an inch below the tubercle on the upper border. Henle mentions a foramen occurring occasionally for the passage of the superior laryngeal nerve, but I can find no record of a case where the artery accompanied the nerve.

Congenital absence of the Soft Palate.—In a male subject aged about 40, there was complete absence of the soft palate. The hard palate was covered with mucous membrane, which was continuous around the posterior edge of the hard palate with that of the nares. The hard palate was well formed, and measured 2½ inches in length and 1½ inches in breadth. The teeth were exceedingly regular and well formed, and not one was missing or decayed.

The Eustachian cartilages were of small size, and their outer edges were continuous with the posterior edge of the covering of the hard palate by a tendinous arch, to which was attached also the superior

constrictor muscle. The openings of the tubes were situated higher up than usual, on a level with the upper wall of the superior meatus, and quite close together on each side of the nasal septum. The bag of the pharynx, which was attached to the basilar portion of the occipital bone, was of great thickness, and fibro-cartilaginous in character. The levatores palati muscles as well as the uvular muscles were absent. The tensores palati muscles were fairly developed, and after passing around the hamular process were attached to some fibrous tissue over that process.

There were no traces of ulceration or of any disease about the throat. From the scanty information I could get of the man, I found that he had been in a lunatic asylum, and that previous to that he had been a local preacher. I could not learn positively that his speech was not affected, but it was not so much affected as to interfere with his occupation. The altered position of the openings of the Eustachian tubes would go to prove that this was a case of congenital absence of the soft palate.

REMARKABLE ABNORMALITY OF THE MUSCULUS BICEPS FLEXOR CRURIS.

By W. D. Halliburton, B.Sc. (Lond.), *Student of Medicine, University College, London.*

A remarkable muscular abnormality was noticed in the posterior region of the right lower extremity of a female subject, which came into the dissecting-room of University College, London, during the month of May 1880. The muscles concerned were the biceps flexor cruris and the gastrocnemius, and the abnormality may be briefly stated as consisting of a supernumerary two-bellied slip of the biceps being continued into the gastrocnemius and forming a third head of that muscle. Though one-bellied slips of a similar sort have been seen several times before, the variety with two fleshy bellies has only once been described; it has, therefore, been thought that the second occurrence of this peculiar arrangement is worthy of record.

The long head of the biceps arose in the usual way, but at the junction of its upper and middle thirds it divided into two fleshy slips, the contiguous surfaces of which were slightly tendinous for about an inch. The outer and larger of these were joined by the short head, forming a muscle, which had the usual size and insertion of the biceps. The inner and smaller slip lay between the rest of the long head, and the semitendinosus, resting on the semimembranosus; at the upper angle of the popliteal space it lay over the line of the internal popliteal nerve; it came off from the inner side of the long head just where its tendinous fibres ceased, 9·5 inches (23·7 cm.) from the head of the fibula, and 4 inches (10 cm.) from the separation of the semitendinosus

from the long head of the biceps. The line of its separation from the long head was oblique in direction, running downwards and forwards; this line was therefore much longer than the width of the belly; its length was 1·7 inches (4·2 cm.), while the width of the belly was only ·6 inch (1·5 cm.); it gradually tapered downwards, being compressed from side to side, and was about 6 inches (15 cm.) in length. At the top of the popliteal space it gave rise to a roundish tendon, and a second belly arose from this, opposite the bend of the knee; this intervening tendon was 1·5 inches (4 cm.) long, and ·2 inch broad; it lay over the line of the internal popliteal nerve, and was covered by the popliteal fascia. Most of the fibres of this tendon were continued into a flattened aponeurotic slip, which ran outwards and downwards, and was attached to the head of the fibula, posterior to the insertion of the rest of the biceps. This aponeurotic slip was continuous upwards and downwards with the deep fascia, so that it was superficial to all the contents of the popliteal space; it was about ·5 inch (1·3 cm) broad, and at its insertion into the fibula it spread out, having a width of ·9 inch (2·3 cm.); its length was 2·5 inches (6·3 cm.); before the fascia was removed it appeared as a thickened band in it; it lay over the outer head of the gastrocnemius, the peroneal nerve, the tibial communicating, and peroneal communicating nerves. The second fleshy belly sprung from the tendon just where it spread out to form the aponeurotic slip just described. It was superficial in the calf, lying in the groove between the two heads of the gastrocnemius; it was fusiform in shape and roundish in section; it soon became tendinous on its anterior or deep aspect, so that it decreased in size as it went downwards; it joined the gastrocnemius in the middle line about an inch below the union of the two bellies, and 10·5 inches (27 cm.) above the os calcis; its tendinous fibres joined the intervening tendon common to the two bellies, and so ultimately were continued into the tendo Achillis, while the few fleshy fibres it had left when it reached the gastrocnemius went to the inner belly of that muscle; it had a length of 6·1 inches (15 cm.) and a breadth of ·5 inch (1·3 cm.) in its widest part. The line of its insertion into the tendon of the gastrocnemius was vertical in direction, and about half an inch in length. The short saphenous vein lay to the outer side of this lower belly in its lower part; it then went under the muscle, and for the upper inch was on its inner side.

Although of the two heads of the gastrocnemius the inner was the more bulky, the outer was the longer, and ended on the common tendon about an inch lower than the inner. The total length of the abnormal slip was 13·6 inches (34 cm.) The plantaris muscle was entirely absent.

The cases of supernumerary slips going from the biceps to the gastrocnemius, which have been recorded, are the following:—

It was first seen by W. G. Kelch [1] on both sides of a body; this

[1] *Beitrage z. Pathol. Anatomie*, Berlin, 1813, 8, s. 42, art. xxxvi., "Abweichung des Biceps Femoris."

was a one-bellied slip which arose from the inner side of the biceps, and terminated by a strong and stout tendon, which was closely united to the lower end of the tendo Achillis.

The other cases in which a similar thing has occurred were all met with and recorded by Dr Wenzel Gruber,[1] of St Petersburg, and are three in number. The first of these was seen in December 1855. It arose from the anterior surface of long head of the biceps above the union with the short head; it remained fleshy till 4 cm. (1·5 inches) above the union of the two heads of the gastrocnemius, where it gave rise to a ribbon-like tendon, which ended in the intervening tendon of the gastrocnemius. This only occurred on the right side of the body. The second case was also that of a one-bellied slip, and it occurred in both limbs; it was met with in April 1856. In the right leg it separated in the same way as the others from the long head of the biceps; it remained fleshy as far as the lower part of the popliteal space; it then became tendinous, and the tendon was inserted into the common tendon of the gastrocnemius, 10 cm. (4 inches) above the insertion of the tendo Achillis; in the left extremity there was a slight variation from this, in the existence of an aponeurosis of origin. This arose from the inner side of the biceps below the union of the two heads, also partly from the popliteal fascia; it was succeeded by a short fleshy belly which was superficial to the contents of the popliteal space, and gave way opposite the bend of the knee to the tendon of insertion, this became aponeurotic, spreading over the lower fleshy part of the internal head of the gastrocnemius.

The third and remaining case was that of a two-bellied slip. On account of the resemblance between it and the present case it is necessary to compare them together more closely. Gruber met with it on both sides of a man in the month of October 1878. It is described fully in the work before quoted, and is figured in plate 5, fig. 1, which accompanies that book. The following is an epitome of his very minute description of it:—

On the right leg.—Its upper belly arose from the inner side and the adjacent parts of the anterior and posterior surfaces of the long head of the biceps; it tapered gradually downwards, being compressed from side to side, and terminated in a rather flat tendon half way down the popliteal space; opposite the intercondylar space of the femur it gave rise to a second fleshy belly, which lay first in the lower part of the popliteal space, and then in the groove between the two heads of the gastrocnemius; about opposite the middle of the calf it again became a long tendon, which was inserted into the part of the tendo Achillis prolonged down from the inner head of the gastrocnemius 4 cm. (1·5 inches) above its insertion into the calcaneum. The inner border of the tendon of insertion from the level of the end of the internal fleshy belly of the gastrocnemius to its insertion into the tendo Achillis was joined by the outer border of a triangular aponeurotic layer which

[1] *Beobachtungen aus der Menschlichen und vergleichenden Anatomie*, von Dr W. Gruber, II. Heft, pp. 56–58. Berlin 1879

arose from the tendo Achillis at the end of the fleshy part of the internal head of the gastrocnemius. It was superficial in the thigh, popliteal region, and calf, being covered only by skin, superficial fascia, and deep fascia; the tibial communicating nerve passed under it. Its total length was 63 cm. (25·2 inches.)

On the left leg.—The arrangement was almost precisely the same; the abnormal slip began 2 cm. higher up, and ended 2 cm. lower down; the intervening tendon was shorter, and the upper belly received a tendinous bundle from the tendinous intersection of the semitendinous. On both sides the plantaris was absent.

We thus see that Gruber's and the present cases are exceedingly similar; the variations between them being only in minor points. In Gruber's case there was no aponeurotic slip to the fibula, and the total length of the muscle was greater. In the case I have described there was no long tendon of insertion at the lower end, and consequently no aponeurotic expansion from the tendo Achillis to it. Gruber remarks at the end of his article: "Though no homologous muscle is found in the lower animals, yet the abnormality just described (which, when he wrote, he called unique) does not on that account become uninteresting." This, then, is clearly not a case of reversion, but the close resemblance between the two cases would, however, point to some common cause.

It now only remains to me to express my indebtedness to Professor Thane for his kindness in lending me books of reference.

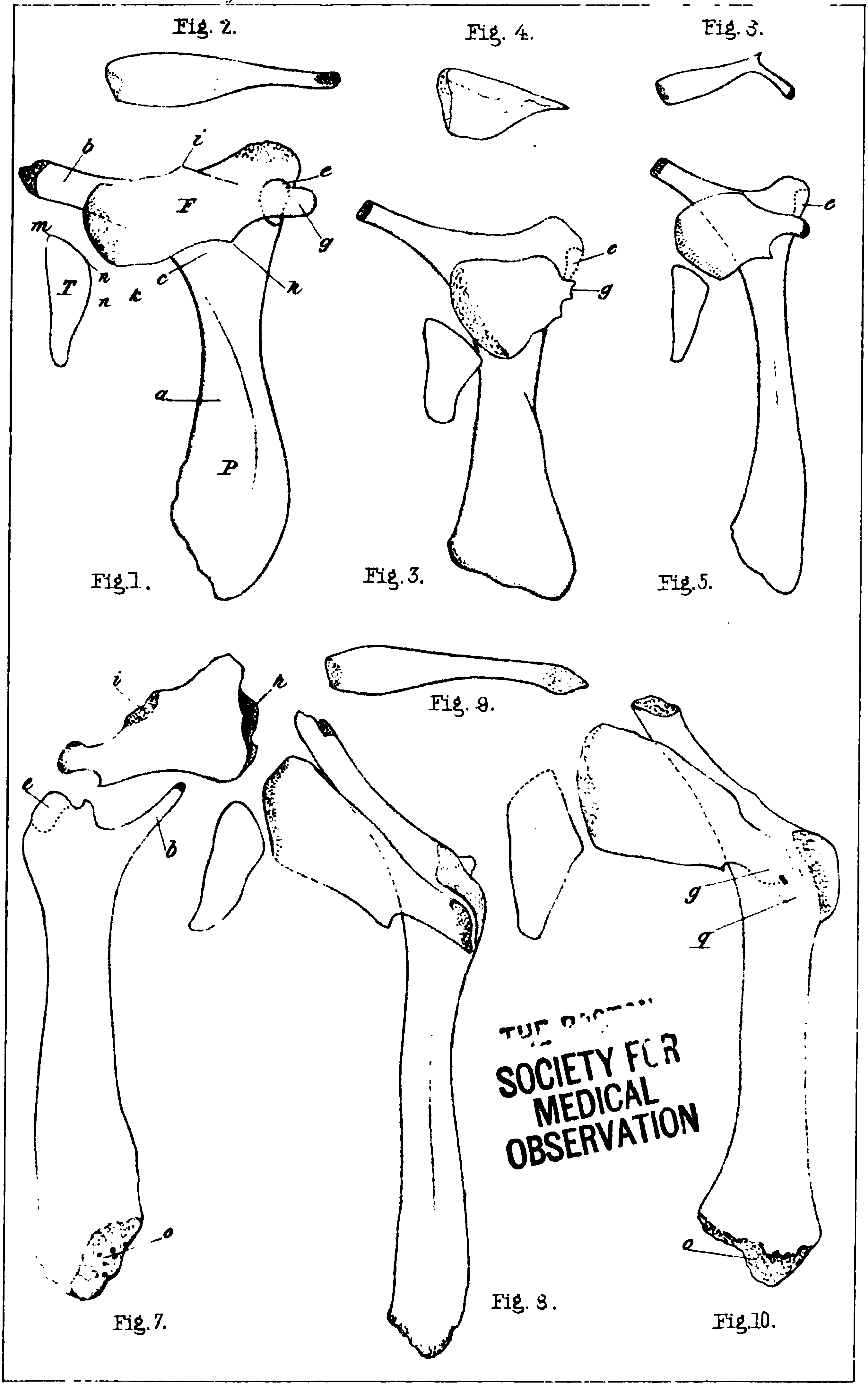
THE PLACENTA AND GENERATIVE APPARATUS OF THE ELEPHANT. By H. C. Chapman. M.D. (*Journal of the Academy of Natural Sciences of Philadelphia*, vol. viii., with 3 plates, 1880).

(*Abstract by Professor Turner.*)

Dr Chapman's memoir is one of much interest. A female Indian elephant in the menagerie of Cooper and Bailey received the male several times between the 25th May and 20th June 1878. The mode of coitus was the same as with the cow and mare. A young female elephant was born on March 9th, 1880, exactly twenty months and twenty days after the last copulation, or twenty-one months and fifteen days from the first copulation. The period of gestation is therefore from 630 to 656 days. The labour was short; the mother standing on all fours, with one hind foot slightly raised. The head presented. The young elephant stood 30 inches in height, measured from base of trunk to root of tail 35 inches, and weighed 213½ pounds. It sucked with its mouth and not with its trunk.

The placenta of the elephant described by Owen was believed to be about the middle of utero-gestation; this one examined by Chapman was at the full term. The chorion was 5 feet 2½ inches long, and 2 feet 4 inches wide. It was engirdled by a zonary placenta, situated 35 inches from one pole and 20 inches from the other. Its circumference is 5 feet 1 inch, its thickness on an average 2 inches. It has the same average width all round. On each side of the placenta was a brownish granular layer 4 inches wide, and about a line thick, and similar granular matter was scattered over the surface of the placenta, probably maternal in its origin. The villi were arborescent, some as long as the thickness of the placenta, others one-half or one-third as long. Abundant maternal tissue was intermingled with the chorionic villi, so that at least one-fourth of its substance consisted of the uterine mucosa. The deciduate character of the placenta was unquestionable. At each pole of the chorion, a villous patch similar to those seen by Owen was present. The amnion was very large. Its inner surface was studded with whitish hemispherical bodies about one line in diameter, which "appeared to consist of fibres with small bodies interspersed." All trace of the allantois as a distinct sac had disappeared, and there was no appearance of an umbilical vesicle. The funis was 3 inches in diameter, 15 inches long, and contained one vein and two arteries; one artery was twice as big as the other.

Chapman then describes the unimpregnated female organs of an African elephant, which are essentially the same as those of the Indian elephant described by Owen, and by Miall and Greenwood.



John Struthers, del.t Gibb & Hay, Lith.rs Aberdeen.

RUDIMENTARY HIND-LIMB OF GREENLAND RIGHT-WHALE. THE BONES.

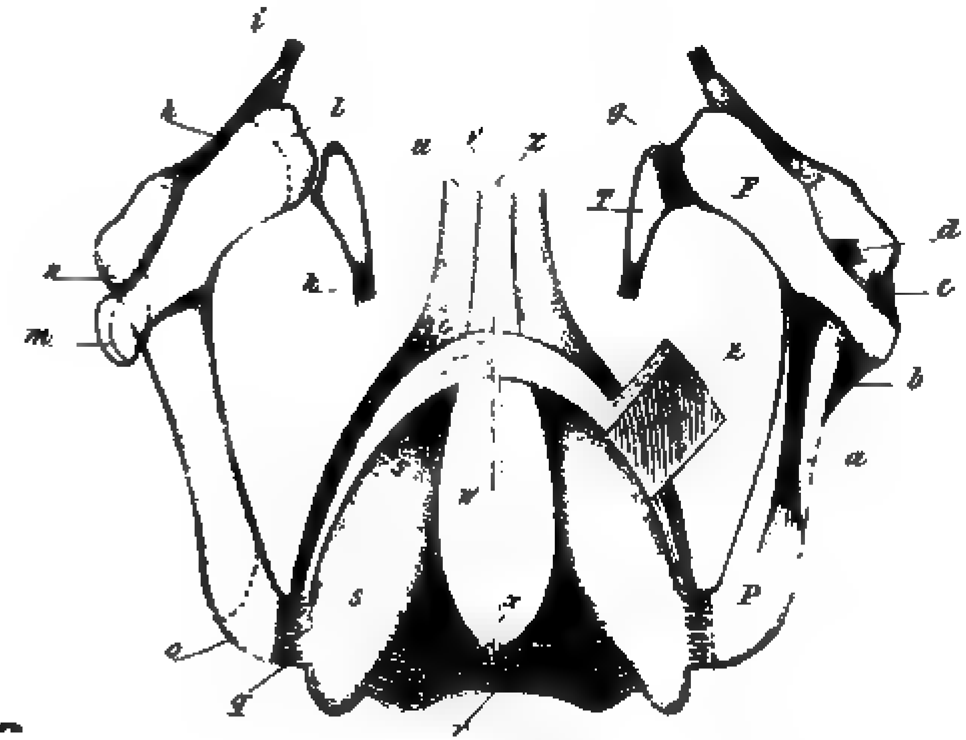


Fig. 12.

Fig. 11

John Struthers del^t

Gibb & Hay Lith^rs Aberdeen

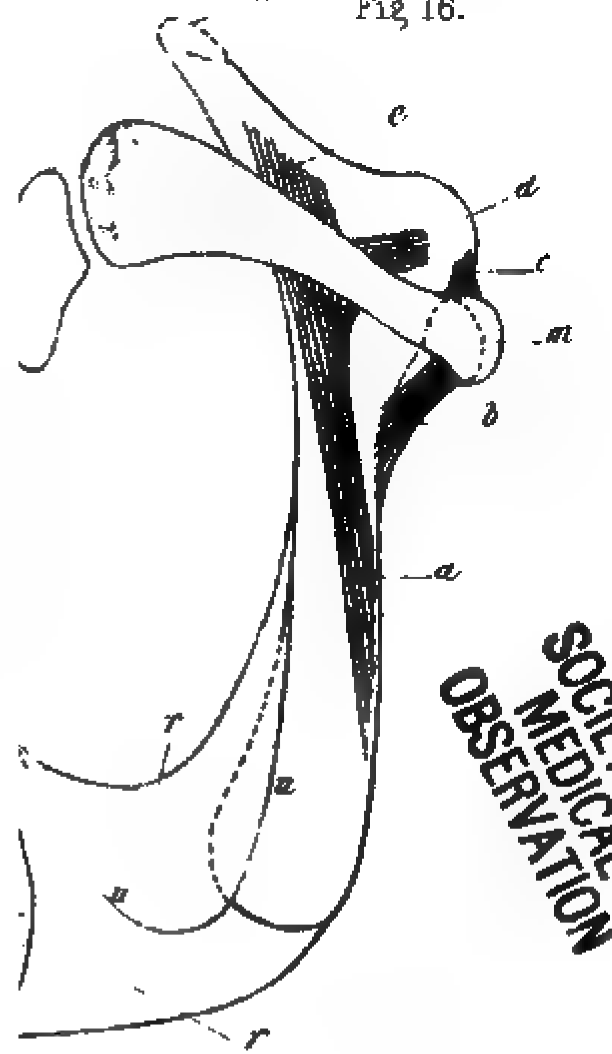
RUDIMENTARY HIND-LIMB OF GREENLAND RIGHT-WHALE THE LIGAMENTS &c

John Struthers del.

Gibb & Hay Lithrs Aberdeen

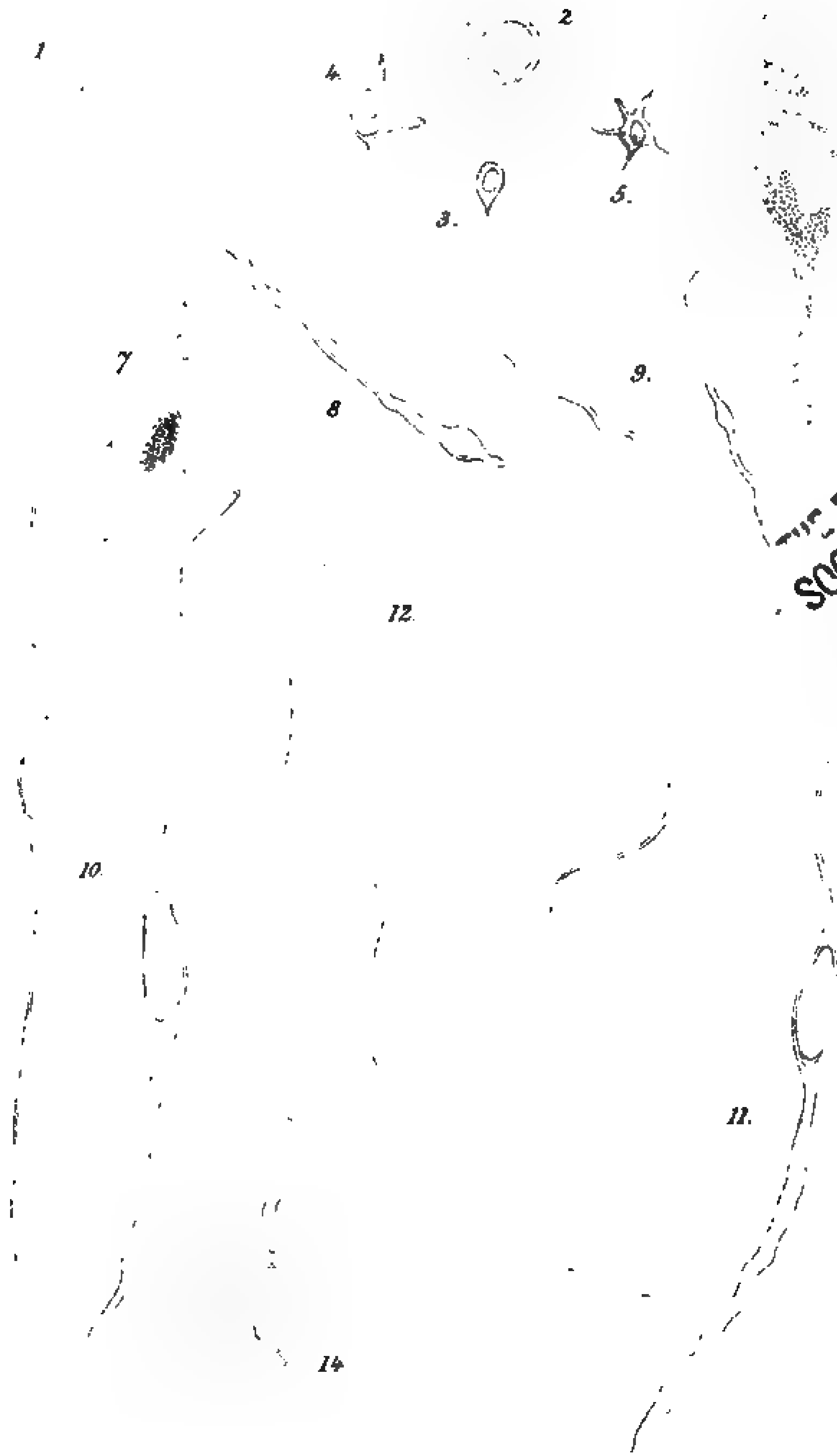
RUDIMENTARY HIND LIMB OF GREENLAND RIGHT-WHALE. THE MUSCLES, MALE

Fig. 16.



Gibb & Hay Lithʳˢ Aberdeen.

RUDIMENTARY HIND-LIMB OF GREENLAND RIGHT WHALE. THE MUSCLES, FEMALE.



F. Huth, Lith.r Edin.r

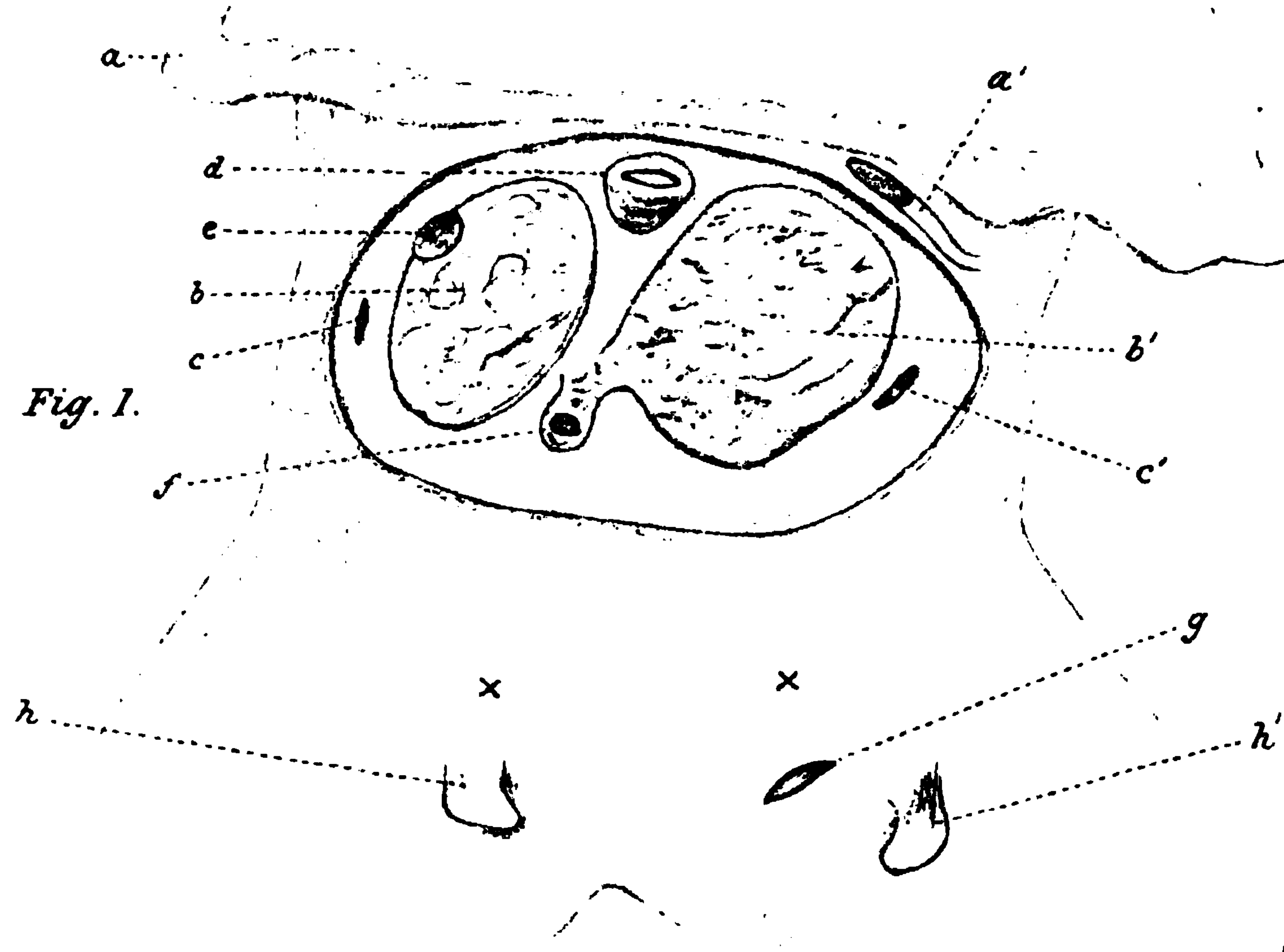


Fig. 1.

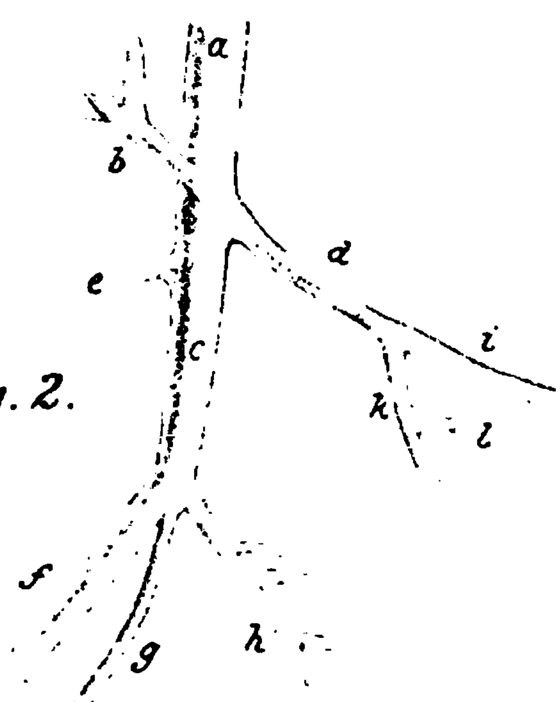


Fig. 2.

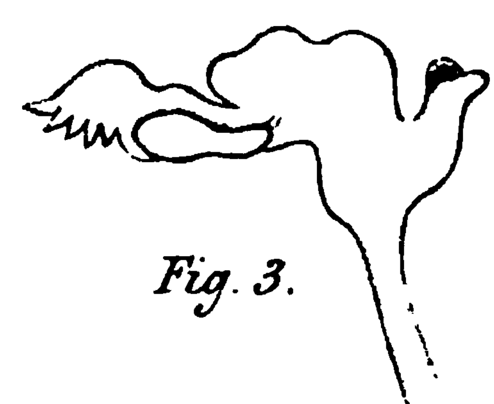
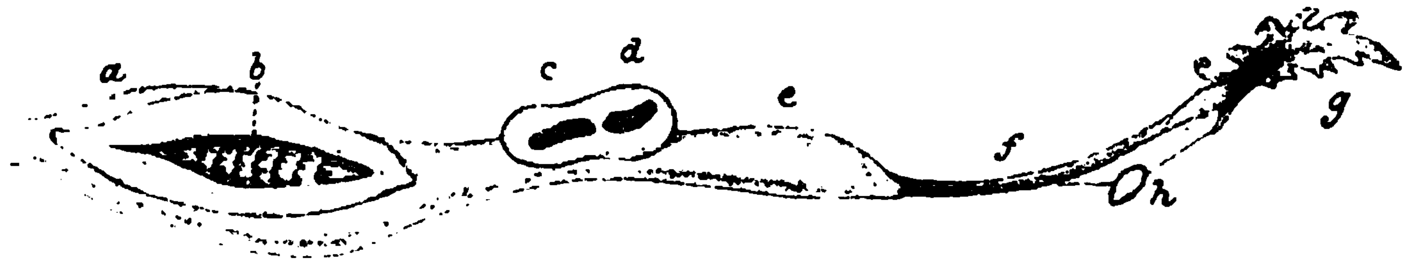


Fig. 3.

Fig. 4.



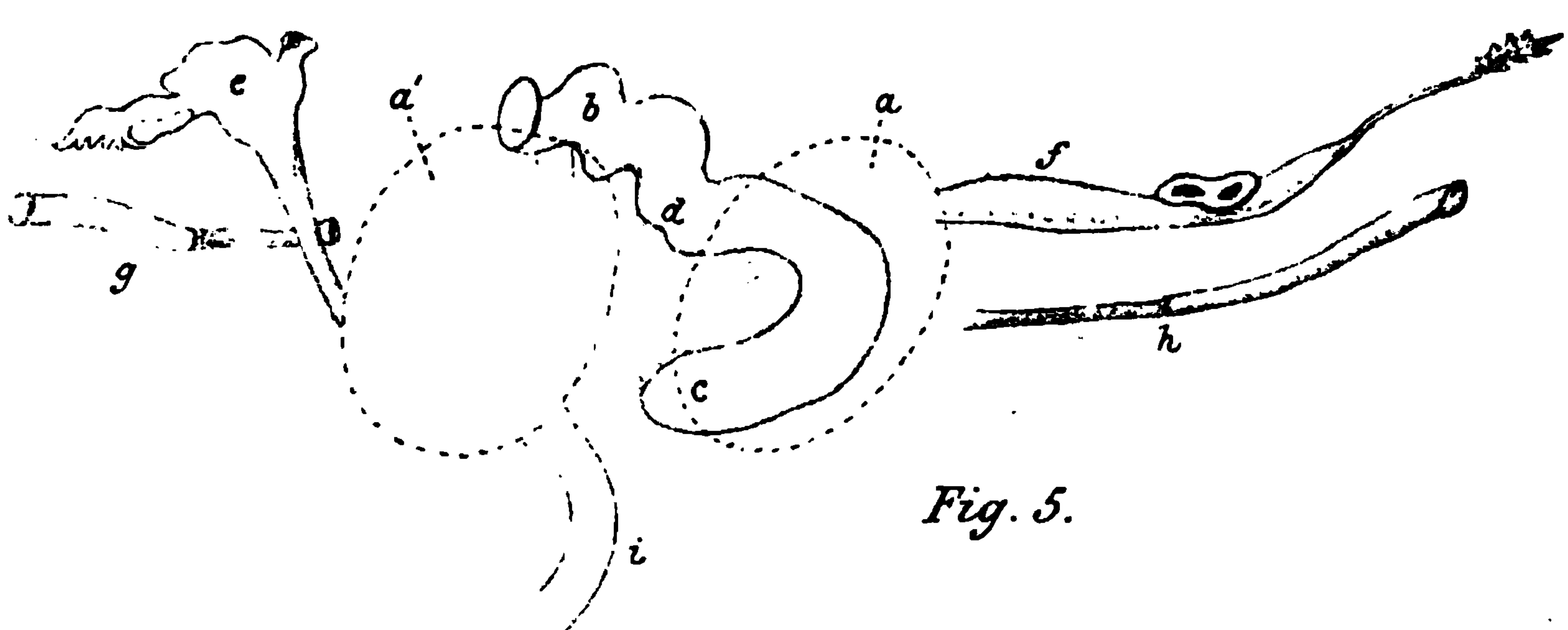


Fig. 5.

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Journal of Anatomy and Physiology.

ON THE BONES, ARTICULATIONS, AND MUSCLES OF THE RUDIMENTARY HIND-LIMB OF THE GREENLAND RIGHT-WHALE (*Balæna mysticetus*).

By JOHN STRUTHERS, M.D., *Professor of Anatomy in the University of Aberdeen.*

(*Continued from page 176.*)

(C.) THE MUSCLES.

THE muscles connected with these bones may be arranged in four groups, three of which connect them with other parts,—(1) internally with the genital organs; (2) a posterior or caudal mass; (3) an anterior or trunk mass; (4) the fourth group those by which these bones are connected to each other.

19. *Relation to the Genital Organs.*—(*a*) *In the male.* Reference in the first place to the drawings and their explanation (figs. 11 and 12, showing both aspects of these parts), will greatly facilitate the understanding of this relation. The following account is from the dissection of the half-grown male, No. I.:—The crus penis has no direct connection with the pelvic bone, but is set upon a great ligament (interpelvic ligament) which connects together the hinder ends of the pelvic bones. The crus begins by a free conical end which projects an inch behind the interpelvic ligament. Seen from above, the crura are of nearly uniform diameter (about 2 inches), and rounded in form, but larger transversely than vertically, and, after an oblique course of about 6 inches, unite in a broad common body, from which the single corpus cavernosum, scarcely larger than one of the crura, and more or less compressed laterally, is sent forwards. The space between the converging crura is occupied by

a strong ligament (triangular ligament) which is pierced near its fore part by the urethra, and is partly concealed on the under aspect by the bulb of the corpus spongiosum, which projects backwards behind the point where the urethra enters it. On its under aspect the crus forms an ovoid enlargement or bulb, caused partly by a development of erectile medulla, partly by a great thickening of the fibrous cortex on this aspect.[1]

[1] The differences of the internal structure of the penis before and behind the horse-shoe septum may be shortly noted here, as they are not without relation to the surrounding muscles. *Behind the horse-shoe septum*, the *bulb of the corpus spongiosum*, 5 to 6 inches in length by about 2 in breadth, is seen on section to be composed of erectile tissue enclosed in a white fibrous covering. The latter is $\frac{1}{4}$ inch thick behind, gradually becoming thinner forwards to $\frac{1}{8}$ or $\frac{1}{16}$ inch; but at the horse-shoe septum it is $\frac{3}{8}$ thick. All along the middle line it attaches the mesial septum between the posterior compressor muscles. The erectile tissue is loosely reticular, and presents many large and small vascular mouths. In the part behind the entrance of the urethra, about 2 inches in length, the erectile mass is semicircular in form, $1\frac{3}{4}$ by 1 inch, but only half that behind, where the cortex is thick. After the urethra has entered, the mass becomes smaller and more depressed ($1\frac{1}{2}$ by $\frac{3}{4}$ inch), the urethra adhering to the slightly concave upper wall. The *triangular ligament* forms the enclosing wall above. This ligament is continuous on each side with the fibrous tissue of the crus, and behind with the interpelvic ligament. It is a thick and firm structure, at first $\frac{3}{8}$ thick, thinner towards the perforation for the urethra, and here the fibres, instead of being transverse, curve forwards and outwards on each side of the urethral aperture. A number of arteries, 8 or 9 large and several smaller, here enter the crus, and several of large size enter the crus earlier and farther out opposite where the erectile tissue of the crus begins. The *crus penis* for the first two inches, including the conical end, is solid, composed of fibrous tissue densely interwoven. The rest of the crus contains an elongated *medulla* of erectile tissue, in the collapsed state about the size of the forefinger, largest transversely; but the fibrous cortex is easily stretched by the forceps to twice that diameter. It is finely reticular erectile tissue, showing some large and many small vascular mouths, the reticulum less open than that of the erectile tissue of the bulb. Its brown colour and open texture mark it off everywhere abruptly from the dense white fibrous tissue of the cortex, but the trabeculæ are continuous with the cortex. This erectile medulla commences abruptly by a rounded end nearly on a level with where the fore part of the interpelvic ligament joins the crus; is largest 2 inches in front of this, diminishes a little along the anterior third of the crus, and finally at the horse-shoe septum unites with its fellow in the single and very differently-constructed medulla of the corpus cavernosum. The *fibrous cortex* is much thicker on the under than on the upper aspect of the crus; $\frac{3}{8}$ inch above, below nearly 1 inch. The fibres are arranged circularly round the medulla, except those which give the increased thickness below. Here there is, as it were, a superimposed stratum forming more than half the thickness of the wall, composed of coarsely interlacing bundles, partly radiating to where they run out as the horse-shoe septum, and behind it running out in rough ridges on the surface in the direction of the fibres of the posterior compressor muscle. Over this area the

The Interpelvic Ligament above noticed is attached to the blunt posterior end of the pelvic bone (the cartilage intervening) like a fibrous continuation of the bone. Here it is 1½ inch thick antero-posteriorly by 1 inch vertically, composed of soft flexible white fibrous tissue. After a length of nearly an inch it supports and mainly ends on the enlarging crus, but sends strong bundles

surface of the crus is thus rendered hard and roughly streaked in contrast with the smoothness of other parts of the crus. Where the crura first unite, the white fibrous tissue, besides encircling the erectile medullæ (here 3 inches apart), forms a great transverse commissure ¾ inch thick vertically, but along the next 3 inches, till the erectile medullæ meet, the transverse commissural arrangement of the intervening fibrous tissue is replaced gradually by an interlacement, and then by a breaking up into vertical bundles.

In front of the horse-shoe septum, sections of the part surrounded by the anterior compressor muscle show a different internal structure from that of the crura, or of the part in front of the muscle. The whole organ is flattened laterally, the medulla of the corpus cavernosum, also compressed laterally, has little of the erectile character, and the corpus spongiosum becomes smaller and more rounded. The proportions are seen in fig. 15, showing a transverse section made 3 inches in front of the horse-shoe septum, about midway between that septum and the back of the broad dorsal interval. Here the sizes are,—the whole organ, without the mesial septa of the muscles, vertically 4 inches, transversely, at the broadest part, 1¾; medulla of c.c., 1 inch by ⅝ inch; c.s. vertically, 1¼ by 1 inch. The organ is less flattened at first, and also forwards as it emerges from the muscle, presenting more a vertically oval form. The medulla of the c.c. is distinctly enough marked off by its brown colour and softness. At first it is blunt-pointed above, flattened at the sides (¾ by ½ inch), and presents an obscure white fibrous septum rising from below, between which and the fibrous cortex passes the fine fibrous tissue which appears to form the bulk of the medulla. The fibrous cortex is thicker than the medulla, except below, where it is only ¼ inch thick. Towards the fore part of the muscle the medulla becomes gradually broader, and trabeculæ radiate from the thick solid septum below. Just in front of the muscle the medulla is semicircular, 1 inch both ways, and the radiating trabeculæ are more marked. At first the medulla contains at its upper part two large vascular mouths, represented farther forwards by one large mouth nearly ¼ inch in diameter and nearly as large as the urethra. No other channels are seen until the medulla begins to broaden and become marked by radiating trabeculæ, when, instead of one large vessel, there may be twenty of good size arranged mostly at the sides and top, the largest not at the top. The *corpus spongiosum* continues to present the same open erectile tissue, at first 1¼ inch transversely by ¾ vertically in the collapsed condition. It diminishes forwards until, on emerging from the muscle, the entire mass is only half an inch in diameter, and now of a rounded form, having farther back been of a vertically oval form. The enclosing fibrous cortex is about ¼ inch thick. The *urethra* is now surrounded by the erectile tissue, but lies towards the top. Though not over ¼ inch in diameter in the sections, the urethra admits of being greatly distended, so as easily to admit the forefinger where the corpus spongiosum is large enough.

over the deep aspect of the crus to join its fellow of the opposite side, thus forming a strong transverse ligament uniting the two pelvic bones. Its free posterior edge forms a prominence internal to the apex of the crus and is then concave. The length of the ligament between the cartilages is 8 inches, between the crura penis fully 4 inches, and here it is fully half an inch thick.

In the full-grown male, No. VII., only the parts near the bone remained. The *interpelvic ligament* was much larger than in No. I., about 2½ inches thick at the end of the bone. It sent two strong prolongations on the bone,—one on the superficial aspect for about 5 inches as a fibrous ridge, prismatic in section, its sides increasing the surface for the muscles attached here, and some of the fibres of the great posterior ligament of the femur arose from it; the other along the inner side of the bone, at first sharply prismatic and then gradually less, until it subsided 4 or 5 inches forwards, presenting an approach to the greater expansion here in the female. The remarkable difference in size and form of the hinder end of the pelvic bone in Nos. VII. and VIII. is noted under section 4. These prolongations in No. VII. may have been partly related to the tapering form of the end of the bone, while the great blunt end in No. VIII. would seem to imply the abrupt attachment of an enormous interpelvic ligament.

The Genital Muscles.—A glance at the drawings (figs. 13 and 14) will show that the crura penis and first 12 inches of the corpus cavernosum are enclosed by a great tubular muscular mass. On the upper aspect it appears as one muscle (the great compressor), mostly meeting its fellow in a median raphé, which is the free edge of a fibrous septum, but separated at the fore part by a broad elongated interval in which the corpus cavernosum appears. On the under aspect another median raphé, also the free edge of a deep fibrous septum, runs the whole length, but the muscular mass is divided by a semicircular raphé, the free edge of a deep fibrous septum (horse-shoe septum) into an anterior and posterior portion. The anterior (the great compressor) is continuous with, or part of, the great muscle seen on the upper aspect; the posterior (posterior compressor) is completely cut off from it by the septum, and is concealed at the sides and behind by another muscle (levator ani), also attached

to the horse-shoe septum, from which it passes backwards to a superficial median raphé and behind that to the rectum, separated from the posterior compressor by the rope-like retractor muscle.

(1.) *The great Compressor Muscle* arises continuously from four different parts. First, as seen on the *upper aspect* (fig. 14, *l*), it arises from the whole length of the inner slope of the body of the pelvic bone, and from the inner border as far forwards as the middle of the angular region, a length of 8¼ inches in this half-grown specimen. The fibres, in large bundles, pass obliquely forwards and inwards, and are inserted into the mesial raphé and septum. The inner part of this aspect of the crus penis is only covered by the muscle, separated by loose areolar tissue, but the muscle is attached to the outer part of this aspect of the crus, arising from it behind the pelvic bone, the deeper fibres soon inserted into it farther on, while the more superficial pass to the mesial septum. In the triangular space between the two muscles, before they meet (5 inches forwards) in the raphé, are seen the triangular ligament and the neck of the bladder, with its thick red muscular walls, seen under the microscope to be composed of striped fibre. Towards the back part the muscle is 2½ inches thick; near the fore part of the narrow mesial raphé, 1 inch thick. The whole length of the insertion is 14½ inches, 9 of which belong to the narrow median raphé. The muscular bundles in front of this, opposite the broad white interval (which is 6½ inches long by 1¼ to 1½ broad), are derived from the origins of the muscle on the *under aspect*. These (fig. 13, *l*) are, from the inner slope of the under aspect of the pelvic bone, by fully as much in breadth and in forward extent as on the upper aspect; from the whole anterior wall of the horse-shoe septum, and from the crus and corpus cavernosum in front of that septum; and lastly, from the mesial raphé and septum, for a length of 11 inches. From these origins the fibres, in thick bundles, pass upwards and outwards round the sides of the crus and corpus cavernosum, forming semi-spirals as they pass to the upper aspect, now with a forward and inward direction, to be inserted into the corpus cavernosum; the more anterior and more superficial fibres reaching to the sides of the white interval above noticed, the more posterior and deeper

fibres terminating farther back and farther out on the sides of the flattened corpus cavernosum. Thus the whole surface of the corpus cavernosum has muscular fibres closely attached to it, the deepest passing from one part of the penis to another. This vast muscle in Mysticetus corresponds to two muscles in human anatomy; the part from the inner slope on both aspects of the bone to the erector penis (ischio-cavernosus), enormously developed; the part from the mesial raphé, on the under surface, to the anterior part of the accelerator urinæ (bulbo-cavernosus); the part from the front wall of the horse-shoe septum here renders the two muscles continuous.

The great thickness of the muscular mass surrounding the penis here is shown in fig. 15, the section being made 3 inches in front of the horse-shoe septum. The semilunar mass on each side, 7 inches vertically, is $2\frac{1}{2}$ to 3 inches in thickness. The inferior mesial septum here is $2\frac{1}{2}$ inches in depth, $1\frac{1}{2}$ at midway, and diminishes forwards. The supporting and compressing power of such a mass of muscle must be enormous.

The *horse-shoe septum* shows itself as a raphé on the surface (fig. 13), and, when dissected, is seen to be a great septum completely separating the muscles and attached to the penis. It begins just within the hinder ends of the pelvic bones and crosses the mesial line 6 inches in front of this. The place of attachment to the penis is shown in fig. 11, part on one side being left entire to show the depth. At the middle of each side it is 2 to $2\frac{1}{2}$ inches deep, diminishing outwards, and also less where it crosses the corpus spongiosum. At halfway to the surface it is about $\frac{1}{6}$ inch thick, at its attachment to the crus about $\frac{1}{2}$ inch, where it crosses the corpus spongiosum 1 inch in thickness. Its attachment along the side of the crus is much nearer the under than the upper aspect, and the direction of the septum as it lies between the muscles is oblique forwards and outwards. The whole anterior surface attaching the great compressor muscle is comparatively smooth, the posterior surface is coarsely ridged in the direction of the fibres of the posterior compressor, and in continuation of like ridges on the hard surface of the crus behind it. In sections the septum appears as if a prolongation of the special fibrous stratum which thickens the under surface of the crus, and may be regarded as a con-

tinuation of that stratum, shelving to the surface in relation to the attachment and action of the posterior compressor-muscle.

(2.) *The Posterior Compressor Muscle* (fig. 13, *m*) arises from the median raphé and septum, extending from the horse-shoe septum to a little behind the bulb, where the mesial septum is attached to the triangular ligament. The median septum at midway is over 1 inch in depth. The fibres in thick bundles pass obliquely forwards and outwards, the anterior bundles more forwards, the posterior bundles more outwards, to be inserted into the whole fibrous surface covered by the muscle, the deeper into the fibrous coat of the bulb, the most superficial into the hinder surface of the horse-shoe septum, the intervening and greater part into the hard fibrous surface of the crus. Internal to the middle the muscle is fully 2 inches thick, halfway out 1½, becoming thinner outwards, but a thick muscle throughout. The most posterior fibres of the muscle are nearly transverse in direction, and are attached internally to the triangular ligament where the median septum joins it. Just behind this is a separate transverse bundle of the bulk of the little finger, but more flattened, attached to the free conical end of the crus, and passing across to the opposite side without interruption or intersection.

Action of these Muscles.—The general effect of these muscles must be support and powerful compression of the parts of the penis on which they lie. The posterior muscle will compress strongly the bulb of the corpus spongiosum and the urethra, and by its outer part the bulb of the crus, assisted in this by the counter pressure of the back part of the great muscle on the dorsal aspect. The presence of the horse-shoe septum will enable the posterior muscle to act specially on these parts. The anterior muscle will, by its tubular form, powerfully support and compress the penis in front of the crura, and at the same time draw the pelvic bones inwards. The crura penis having no direct bony attachment, it is not very evident how the penis can be firmly supported unless the interpelvic ligament can be tightened, but it is not evident by what muscular action the pelvic bones can be pulled outwards behind. The enlargement of the crura, surrounded and grasped by the great muscles coming from the pelvic bones, may serve to give sufficient fixity to the organ, converting the pelvic bones and penis

into one firm mass, while the muscles at the same time will expel the contents of the urethra.

(3.) *Levator Ani Muscle.*—As the back part of this muscle was mutilated and only a short part of the rectum present, I am not quite certain of the correctness of the name. As seen in fig. 13, *i*, it arises from the outer half of the horse-shoe septum, superficial to the attachment of the posterior compressor, and, backwards, from the fibrous tissue at the hinder end of the pelvic bone. The bundles curve inwards and backwards, the internal, nearly half the muscle, meeting their fellows, after a course of about 5 inches, in a median raphe in front of the rectum, for 2½ inches. The outer and thicker half of the muscle was divided where the bundles appeared to have been passing back by the side of the rectum, only one large bundle, the size of the little finger, having been left in the mutilated parts, passing to and spreading on the side of the rectum, where the divided ends of other red bundles were also seen. It is a strong muscle, 1½ inch thick behind, 1 inch at the middle, diminishing forwards to a thin free edge, where it conceals the outer and back parts of the posterior compressor, from which it is soon separated by areolar tissue and fat and internally by the rope-like retractor muscle. Apparently assisting the muscle in supporting the rectum, is a considerable fibrous bundle (fig. 14, *t*), attached above to the prominence on the free edge of the triangular ligament, and passing downwards and inwards to the side of the rectum, on which it spreads, in continuity with pale muscular bundles.[1]

[1] *The rope-like Retractor Muscle.*—Only the posterior attachments and perineal stage of this rope-like body remained. As seen in fig. 13, *k*, lying between the levator ani and the deep compressor muscle, it is of a rounded form, about the thickness of the fore finger or thumb, and near its fellow of the opposite side. It is enclosed in a strong but soft fibrous sheath, of a white colour, and internally is composed, among plentiful areolar tissue, of pale yellow bundles disposed longitudinally, which, under the microscope, are seen to be made of unstriped muscular fibre. Traced backwards, it becomes flattened between the levator ani and the posterior compressor, turns round the free edge of the triangular ligament, and breaking up into several longitudinal fasciculi, is attached to the neck of the bladder by tendinous bands, the chief band close to the middle line. Four inches after its origin from the bladder and 1 inch after it has appeared below the triangular ligament, it receives a fasciculus from the side of the rectum, but the origin from the bladder is much larger than that from the rectum. In the figs., 13 and 14, the rectal connection is seen on the right side only, the left side having been cleared. The bundles are continued on the rectum in pale circular

(*b.*) *In the female*, the *interpelvic ligament* is a great structure. As seen in fig. 16, *rr*, besides being attached to the end of the pelvic bone, it sweeps forward along the inner edge as a projecting ligament, gradually subsiding at about the middle of the posterior division of the bone, into the thick fibrous edging of this border of the bone. From this extensive attachment it passes nearly transversely inwards, the anterior edge thin and deeply concave, so that the transverse portion increases in breadth towards the middle line. I have not had an opportunity of examining its relations at the middle line in the female, 4½ inches being the greatest extent of the transverse part present in any of these specimens. This part measured 6 inches antero-posteriorly at its middle, 7 towards the middle line, but in all the specimens a portion of the back part had been shaved off. At its attachment to the pelvic bone it extends on both surfaces of the bone, and both surfaces of the entire ligament are marked by a curved ridge indicating the extent to which this fibrous mass gives origin to the great genital muscular mass. On the under aspect the surface is concave in front of this ridge, and the ligament thins rapidly to the anterior concave edge; on the deep aspect the surface is abruptly scooped out backwards, so that the muscle sinks into a groove, an inch deep, overlapped by the ridge.

The *genital muscular mass*, in the female, arising from the pelvic bone and interpelvic ligament, is very large, as seen in fig. 17, *ll*, which shows the whole extent of the mass present in any of the specimens. The section of the mass two inches from the bone, measured, in the adult, 12 inches in length and 6 inches in thickness. It arises posteriorly, from the greater part of the transverse portion of the interpelvic ligament, as far back as the curved ridges above noticed; externally, from both surfaces of the antero-posterior part of the same ligament, and beyond it from the inner slope of both surfaces of the pelvic bone as far forwards as in front of the middle of the angular region, this attachment to the pelvic bone corresponding to that of the great compressor in the male; and anteriorly, from the outer half of the beak, at the inner border and a little way on the under surface. The mass forms coarse bundles. A little behind these come the pale circular bundles from the suspensory ligament of the rectum, and soon behind these the more pronounced muscular stratum from the levator ani muscle.

bundles directed obliquely inwards and forwards, but more transversely toward the fore part. The part from the beak, consisting of several large fasciculi, is separated from the rest by loose areolar tissue, and may have been a separate muscle.

20. *The Posterior* or *Caudal Muscular Mass* (figs. 13, 14, 17, and 18, *a*).—This great mass is attached to rather more than the posterior half of the body of the pelvic bone, along the outer border and over both surfaces as far in as the intersecting ridge, approaching there the outermost origins of the great genital mass; and, behind the bone, to the outer and posterior part of the interpelvic ligament. It soon gathers into an ovoid mass, the transverse section of which, two inches behind the pelvic bone, was 7 to 8 inches transversely by 5 inches vertically; in the half-grown male, 4 to 5 inches by 3 inches. As far as present in these specimens, it showed no subdivision. Its direction is apparently inwards as well as backwards, and it may be regarded as a large ischio-caudalis muscle, probably continued backwards to the chevron bones. Acting from behind, it will powerfully retract the pelvic bone and interpelvic ligament, with all the apparatus attached to these parts, the direction of the movement being probably inwards as well as backwards. In the half-grown male, its origin from the interpelvic ligament (for about 1 inch) was bounded internally by a fibrous band or tendon (shown in fig. 14), about the size of the little finger, which after giving orgin outwardly to part of the caudal mass, looped inwards to join the suspensory ligament of the rectum, leaving between them and the outer concave edge of the triangular ligament a well defined oval passage (fig. 14, *u*), admitting three fingers, the contents of which had been removed.

21. *The Anterior* or *Trunk Muscular Mass* (figs. 13, 14, 17, and 18).—This mass of muscle, coming back from some part of the trunk, is attached to the femur and tibia as well as to the pelvic bone. It is larger than the caudal mass. In No. II., on transverse section at four inches from its insertion, it was 10 inches transversely, with an average thickness of 3 inches. There was enough present in this specimen (5 inches) to show a distinction into two muscles,—an external, the great mass, directed backwards and inwards, attached to both femur and pelvic bone; and an internal, in the form of a pyramid, or bunch of pyramids, coming

back from a rounded tendon, directed backwards and outwards, and attached to the femur, tibia, and inner part of the pelvic bone.

(1.) The *internal* or *pyramidal muscle*, or part (fig. 17, b^2, fig. 18 b^1), arises abruptly from a thick transversely oval tendon (about 1 inch of which is present) about the thickness of the thumb. The tendon, however, is continued on the deep aspect of the muscle to the end of the pelvic bone, and expands on the bone for 3 inches outwards. The inner part of this tendinous insertion is as large as a somewhat flattened little finger, but, at least in this specimen, does not appear to correspond to the fibrous tuft noticed in some of the specimens as continued from the cartilaginous end of the bone. The *deep* portion of the muscle arises mostly in an abrupt manner from the rounded tendon, but also from the continuation of the tendon to the pelvic bone; forms a flattened pyramid, 2½ inches by 1 inch in thickness at the middle, and is inserted mainly into the pelvic bone for 3 inches along the anterior border and under surface, and by its outer portion, about a fourth of the whole, to the femur, along its distal 1½ to 2 inches. The *superficial* part of the muscle arises abruptly from the tendon, 4 inches from the femur, as two bundles, each 1 inch thick, passing back in pyramidal form, the outer and larger to be inserted to the distal 3 inches of the anterior border of the femur; the inner, not so broad as the outer, to be inserted into the angle of the femur, the caspule of the knee, and a little upon the tuberosity of the tibia.

(2.) The *external* or *great muscle* (figs. 13, 14, and 18,b), five to six times larger than the internal, shows no subdivision into strata till close to its insertion, which is to the anterior border of the body and neck of the femur, for about four inches, and to the anterior border of the corresponding part of the pelvic bone, also reaching a little on its under surface and outwards to the promontory. This great muscle approaches the outer and middle parts of the femur with an obliquity inwards, while the pyramid-like muscle is directed obliquely outwards to the inner part of the femur, and more directly backwards to the knee joint. Taking the two masses together, the pelvic bone has most of it at the outer part, rather the least at the inner part, but on the whole rather more of it is attached to the pelvic bone than to the femur.

In none of the other specimens was there much of the length of this mass present, and perhaps it was for this reason that no trace was seen of the separation into the two muscles above described. In the half-grown male, the section of the mass, at two inches in front of the pelvis, is 7 inches across, with an average thickness of 2 inches—thicker internally, less externally. In this specimen, No. I., the mass here, and when cut longitudinally, shows no appearance of separation even into femoral and pelvic strata till close to the bones. The deeper stratum is attached to the whole breadth of the beak of the *pelvic bone*, including the cartilage internally, and as far out as the middle of the promontory; the attachment is to the border and a little way on both surfaces of the bone, the fibres fleshy to near the attachment, except the part on the under aspect of the bone near the promontory, where it is tendinous. To the *femur* it is attached to the whole length of the body and outer half of the neck, the most internal part by oblique tendinous fibres, the rest of the insertion fleshy very close to the femur, and attached by short tendinous bundles to the anterior border and over the anterior third of the superficial surface of the body of the bone. To the *tibia* it is attached at the anterior angle and a little way along the inner border, and in front of this it is attached to the capsule of the knee. Taken as a whole, at the outer part of the mass, most of it goes to the pelvic bone; across the middle, most of it is attached to the femur; and the very inner part goes entirely to the femur and tibia; so that, in this subject, the greater part of the mass, probably about $\frac{2}{3}$ of it, goes to the femur and tibia. The part to the tibia is, on section, 1 inch by $\frac{3}{4}$ inch.

(3.) In contact with the deep aspect of this trunk mass, is a *flat expanded muscular layer*, the broad sheet-like tendon of which is attached to the pelvic bone. This tendon, with muscular fibres attached, is seen in figs. 17 and 14, *c*, and the narrow strap-like continuations of it, over the femur, are seen in figs. 13 and 18, *c*. In No. II., in which it was more fully seen, this tendon, 8 inches in length and 2 in breadth, is opposite the outer $\frac{2}{3}$ of the trunk mass. The insertion to the pelvic bone is obliquely across the outer $\frac{2}{3}$ of the upper surface of the transverse part of the pelvic bone; and, beyond the pelvic bone, turning round the outer edge of the great mass and playing over the promontory,

it sends a strap-like continuation which divides into two bands. One of these curves inwards across the neck of the femur to be inserted at or near the trochanter; the other passes backwards over the head of the femur, which it compresses on the outer side, and then skirting along the outer edge of the pelvic bone, and adhering to the longitudinal capsular muscles, finally joins the outer bundles of the caudal muscular mass. The direction of the sheet-like tendon is backwards and inwards, like that of the muscular fibres which end in it. Of these there was present a portion 6 inches broad, 2 inches long, and over ½ inch thick. On its under surface was another muscular portion, 4 inches long, 2 inches broad, and ¼ to ⅙ inch thick, directed backwards and outwards, and continued into the strap-like tendon.

Without a knowledge of the other connections of these anterior muscles, their *homology* must remain uncertain. The sheet-like tendon and muscle suggest the external oblique of the abdominal wall; but the layer, or portion, crossing it diagonally, is rather incompatible with that view (being on the wrong side to represent an internal oblique), unless it be merely a part the direction of which is modified for the strap-like continuation. If the pyramid-like bunch is a pyramidalis abdominis, and the great mass external to it the rectus abdominis, their continuation to the femur is remarkable. If these are adductor and other muscles of the quadrupedal femur continued upwards, that would imply a very remarkable change of the anterior attachments. The observations of authors on the muscles in toothed cetaceans, so far as known to me, throw no light on the nature of these muscles. The conditions are greatly altered in Mysticetus by the presence of a thigh bone and the accompanying transverse part of the pelvic bone. But whatever the nature of these muscles, they will act powerfully, their general *action* being to advance the pelvis either directly or by pulling on the femur. The pyramid-like muscle will pull obliquely forwards and inwards, the flat muscle obliquely outwards, the great intervening mass with, as far as can be judged from the portion present, a little obliquity outwards. The pelvis will be moved forwards and backwards by the alternate action of these and the caudal mass, or be fixed by their joint action. The very slight extent to which movement of the femur on the pelvis is allowed to

take place accords with the very little subdivision of the trunk mass as it passes to these two bones. The action of this great mass on the femur must therefore take effect on the pelvis, doing so through especially the great posterior ligament of the femur. When the mass is pulled, causing advance of the femur, there is a tendency of the hinder edge of the femur to rise (rotation inwards), which is checked chiefly by the same ligament; and there is a backward projection of the head of the femur, which is opposed by the tightening of the strap-like tendon. The action of the considerable bundle which pulls by the tibia is soon resisted by the fibrous structures which attach the tibia posteriorly.

22. *Muscles passing from the Pelvic Bone to the Femur.*—These muscles may be divided into those which encapsule the head of the femur and those which pass to the body of the bone.

(*a.*) The *capsular muscles* are three in number—two longitudinal, one below and one above; and one transverse, situated above.

(1.) The *inferior longitudinal capsular muscle* (figs. 13 and 17, *d*) arises behind from the pelvic bone, as far back as the anterior fibres of the great caudal mass, and internally from the outer side of the great posterior ligament of the femur. In the half-grown male the flesh is about 3 inches in length and ¾ inch in breadth. Passing upon the head of the femur it becomes tendinous at the middle of the head, appearing at first to be attached to the head, and it may be partially so, but on being divided the tendon proper may be dissected off the head, and is seen to be continued forwards and outwards to be inserted into the pelvic bone on the dorsal aspect, in front of the head of the femur. The muscle encapsules the head on the under and outer aspects, and partly on the dorsal aspect. Internally, a thin expansion is continued from the muscle to the neck of the femur, filling up the triangular space between the muscle and the great ligament of the femur. In No. III. this expansion was continued inwards over the fore part of the great ligament, to be attached to the whole length of the posterior border of the shaft of the femur.

(2.) The *superior longitudinal capsular muscle* (fig. 14, *n*), beginning fleshy on the upper aspect of the pelvic bone, passes backwards along the outer side of the bone. Like the last muscle, it loops longitudinally from one part of the pelvic bone

to another, and binds the head of the femur on its upper aspect. Along the outer edge of the bone it is, in the half-grown male, about the same breadth as the inferior muscle (¾ inch); in the full-grown subjects (Nos. II. and III.), about 1½ inch broad, and at the fore part, where, after arising by five or six large bundles, it spreads on the bone, the flesh is 3½ inches broad and ½ to ¾ inch thick. Its origin occupies more than the outer half of the angular region of the bone, between the promontory externally and the insertion of the sheet-like tendon, the oblique line of attachment of which may be recognised on the macerated bone. Posteriorly, becoming tendinous, it is inserted partly into the bone, but largely runs against the outer part of the caudal mass, in common with the continuation of the strap-like tendon which covers it. Part of the caudal mass, as large as a couple of fingers, arises from the tendon of this capsular muscle, and is pulled outwards by it. This gives the caudal mass a pull upon the fore part of the pelvic bone, and might be regarded as an accessory origin to that mass, but the piece of tendon intervenes, and the adaptation seems rather to be that of giving tension to the connecting bundles, and thus more effectually binding down the head of the femur.

(3.) The *transverse capsular muscle* is on the upper aspect. As seen in No. III., it is triangular in form, the flesh 3 inches in length, ½ inch thick; in breadth 3 inches at its origin from the pelvic bone, contracted to 1 inch where it becomes tendinous half-way across the head of the femur. The tendon adheres, and is partly attached, to the head of the femur externally, but when divided can be dissected onwards round the head, as a broad strap expanding over the whole of the under aspect of the head, and terminating on the periosteum where the head joins the neck. This muscle was found only in No. III. Although Nos. I., II., and IV. were carefuly dissected at this part, no trace of this muscle was seen. The great projection and great size of the head in No. III. may possibly account for the presence or great size of this muscle in it.

The head of the femur is thus very effectually enclosed and bound in by the muscles now described. Besides the possibly only occasional transverse muscle found in No. III., these dissections show the presence of three normal encapsuling struc-

tures,—the inferior and superior longitudinal muscles, muscular in the greater part of their length (also mixed with a good deal of fibrous tissue), binding in the head on the under and upper aspects, and, by the union of their contiguous margins, on the outer aspect also; and along the outer side, superficial to these, the continuation backwards of the strap-like tendon, attached behind to the outer side of the caudal mass. This strap, not itself muscular, is made tense by the action of the caudal and anterior trunk masses which it connects, and will not only bind the head of the femur, but enable these masses to press inwards the whole pelvic bone, while they pull on its fore and back parts. The capsular muscles may be regarded as to some extent representing the group of external rotator muscles of the quadrupedal hip.

The *tendinous capsule* thus formed for the head of the femur is the functional capsule, but is not lined by a synovial bursa. The fibrous surface of the head is smooth, but the inner surface of the capsule is lined by flocculent areolar tissue, giving the head sufficient freedom for its limited movements. This quasi-cavity round the head extended, in No. III. (fig. 17), forwards about 1 inch beyond the head, so that the anterior ligament of the head is seen within it; and inwards to the neck, being limited by the insertions of the capsular muscles. It was purely tendinous on the inner surface, externally muscular as above described. It was $\frac{1}{8}$ to $\frac{1}{6}$ inch in thickness, the strap-like tendon forming an additional stratum on the outer side.

(*b*). The *muscles from the pelvic bone to the body of the femur* are four in number; one behind, expanded and thin, reaching also to the tibia (seen in fig. 13, *g′*), and three from the fore part of the pelvic bone (seen in fig. 17, h, h^1, h^2). One of these is on the under surface of the femur, and two occupy an interosseous position, one directed inwards, the other directed outwards to the femur. While each of these muscles is more or less of a flexor, the muscle below the femur abducts, and may be termed the abductor; the two between the bones adduct, and may be termed the internal and external adductors.

(1). The *abductor* (fig. 17, *h*) arises from the promontory close in front of the acetabulum, and from the anterior ligament of the head, passes obliquely inwards and backwards and is in-

serted on the under surface of the femur near the trochanter. It is triangular in form; length along the middle 3½ inches, breadth at origin 1½ inch, at insertion 2 inches; thickness at middle ⅓ to ½ inch. In No. I. it formed a 1-inch equilateral triangle. The outer edge of the muscle adheres to the tendinous capsule, and will assist so far in binding in the head of the femur.

(2). The *external adductor* arises a little in front of the last muscle, and is inserted on the upper surface of the body of the femur not far from the anterior border. In the figure (fig. 17, h^1) it looks like the fellow of the last muscle, passing to the other side of the femur; but its origin may extend inwards on the beak, making the muscle broader and the fibres shorter and less transverse than in the figure. In the half-grown male it was 3½ inches in breadth, the fibres 1½ in length. In No. V. the breadth was 1½, the length 2 inches. The muscle may be partially divided into an outer and an inner part, and the insertion, instead of being on the deep surface, may be on the anterior border and some way on the under surface, as it was in No. VII. The length and breadth in this case were both 2½ inches, the thickness ½ inch. The insertion of the great trunk mass to the femur is between this muscle and the abductor.

(3). The *internal adductor* (fig. 17, h^2), is arranged like an intercostal muscle, the fibres sloping backwards and outwards. Its attachment along the surfaces of the pelvic bone and femur may be for 5 to 6 inches; the length of the bundles about 2 inches, as seen from below, but seen on the deep aspect the external fibres are longer and more oblique. The origin extends along nearly the whole of the beak, and it may be on part of the angular region of the bone, and may occupy all but the most anterior part of the surface. The insertion on the femur is along the deep surface of the shaft and part of the neck, towards the posterior border, but obliquely, so that the outer part is nearer the border than the inner. The thickness varies a good deal; in No. VII. it had the unusual thickness of 1 inch, and was composed of two strata enclosing the deep interosseous ligament. In No. II., a prolongation of this muscle, as thick as a thumb, went back for 4 inches along the deep surface of the

great posterior ligament; the same in Nos. III. and V., but not nearly so large.

Actions and Homology of these Muscles.—The two adductors, besides adducting, flex, rotate out, and cause some gliding, the internal inwards, the external outwards; the abductor, besides abducting, flexes, rotates in, causes some outward gliding, and assists in tightening the capsule of the head. But these movements are so limited, that the use must rather be that of steadying the bone in these directions. Their adducting power is the greatest and will press the femur against the cushion of muscle between the two bones, formed by the adductor muscles and by the part of the trunk mass which fills up the space between them and the femur. Homologically viewed, the internal adductor may be regarded as one of the adductors of the quadrupedal limb; the external adductor as an iliacus internus; the abductor as a portion of one of the deeper glutei.

It was interesting to see the condition of these muscles in No. V., in which the femur on one side was anchylosed. On the left side they were well developed, the internal adductor $\frac{3}{4}$ inch in thickness. On the anchylosed side, the abductor was present but reduced to a fibrous condition, and adhering by the whole of its deep surface; the external adductor had been mutilated, but part of its insertion remained in a muscular condition; the internal adductor was about as large as the same muscle on the movable side, but, on section, was seen to be more mixed with fibrous tissue, which formed about half the bulk of the inner part of the muscle. The muscular prolongation on the great posterior ligament was present, 3 inches in length.

(4). The *posterior muscle of the body of the femur* (fig. 13, *g*), is expanded and thin, and is aponeurotic as well as muscular. In the half-grown male, it occurred as a stratum of muscular fibre supported on its deep surface by an aponeurotic stratum. It arose externally from the inner side of the great posterior ligament of the femur, posteriorly by a narrow part from the hinder end of the pelvic bone, and internal to this from the horse-shoe raphé for several inches, opposite the levator ani and nearly as far in as it. The fibres pass forwards and inwards to be inserted at the posterior edge of the femur from the point of

attachment of the great posterior ligament inwards to the capsule of the knee, the most internal fibres to the posterior or outer border of the tibia. It is from 2 to 3 inches in breadth, about $\frac{1}{8}$ inch thick, the aponeurotic stratum somewhat thinner. The longest fibres, those to the femur, are 6 inches in length; the shortest, those to the tibia, 2 inches. Fully half of the muscle goes to the tibia. It extends the femur and flexes the knee joint, and the aponeurotic stratum gives it great strength in resisting the forward movement of the femur and the inward movement of the tibia. Homologically viewed, it may be regarded as an adductor magnus and a hamstring, proceeding from their quadrupedal origin at the tuber ischii.

In two of the adult female subjects, Nos. II. and III., in which this structure had not been mutilated, it was entirely aponeurotic and more extensive; reaching outwards, over the fore part of the great posterior ligament, so as to receive origin from the pelvic bone, and the fibrous structures over it; and reaching backwards to join the interpelvic ligament. There it conceals the great genital mass, and serves as an aponeurosis to the earlier part of that mass, some of the posterior fibres of the mass arising from its deep surface; but it is quite separate from the mass before it reaches the femur and tibia. This aponeurosis is represented in fig. 18; while fig. 17 shows the parts brought into view by its removal. It was about $\frac{1}{8}$ inch thick, composed of coarse fibrous bundles, having the same direction as those of the muscle in No. I., and serves as a strong resisting structure to forward movement of the femur and tibia. In No. III., on removing this aponeurosis, a distinct red muscular expansion was seen proceeding from the inner edge of the inferior longitudinal capsular muscle, concealing the fore part of the great ligament, and inserted into the whole length of the femur (seen in fig. 17). It adhered to the aponeurosis for 2 inches before it reached its insertion at the posterior border of the shaft of the femur, but at the neck of the bone the insertion was some way forwards on the surface, and separate from the aponeurosis, which was here continuous with the superficial part of the tendinous capsule of the head of the bone.

23. *The Muscular and Tendinous Connections of the Tibia.*—The last described expanded muscle and aponeurosis, or aponeu-

rosis only, is attached along the *outer or posterior edge* of the tibia. In Nos. II. and III. a special band of aponeurosis (shown in fig. 18), passing to the tibia, was placed more transversely and superficially, its fibres at first decussating with the fibres of the general aponeurosis, but at last fused with the fibres of the tibial part of the aponeurosis. Along the *inner edge* of the tibia is attached an aponeurosis, cut short to half an inch in these specimens, the fibres apparently directed inwards and backwards. To the *anterior end*, as noted above, is attached the insertion of the innermost part of the pyramid-like muscle. To the *posterior end* or tip of the tibia is attached what may be termed the longitudinal *tibial band.* This band had been cut short in all the specimens, only from 1 to 4 inches of it remaining, except in No. III., in which it was present in its whole length (as seen in fig. 18, *k, k*), extending backwards to the great interpelvic ligament. It is a flat strap-like band of white fibrous tissue disposed longitudinally; length 10 inches; breadth, at its attachment to the tibia, ½ inch; at the middle, ¾ inch; at its posterior attachment, about 2 inches; thickness, ⅛ to ⅙ inch; in transverse section, flat on the deep surface, convex superficially.

On the deep aspect of this tibial band, and attached to it, between it and the great aponeurosis above described, is a stratum of muscular bundles, forming a *superficial perineal muscle.* As represented in fig. 18, *n, n*, these bundles commence on the transverse part of the great interpelvic ligament and the aponeurosis in front of it, and pass forwards and inwards under cover of the hinder half of the tibial band, showing themselves again along the whole length of the inner side of the band where they had been divided. The part here present forms a triangular stratum, 4 inches in breadth at the base, 5 in length, and ⅙ inch in thickness. The flattened bundles are partly continued past the tibial band, partly attached to it, in a proportion which it was not easy to determine, but a good many, especially those nearest the tibia, arise from the band on its deep surface and inner side, and as far forwards as within an inch of the tibia (seen at *o*, fig. 18); in No. II. still nearer the tibia, and in No. V., they arose quite close to it. On dividing the tibial band, it is seen that it is as it were split by this muscular stratum, the

deeper layer lining the deep surface of the superficial muscular stratum. The tibial band is composed mainly of longitudinal fibres, but connected with the great aponeurosis external to it, to which it forms a kind of longitudinal edging. The aponeurosis and the deep layer of the tibial band adhere behind to the great genital mass as its covering aponeurosis, but as they approach the tibia they are quite free from it, a wide space filled with loose tissue intervening. The outer edge of the superficial layer, or tibial band proper, is not free, but, like the tibia, receives the aponeurosis, being distinguished from it by the direction of its fibres, and there may have been a similar expansion joining its inner edge. This superficial muscle will have some effect in tightening the tibial band, but the connection seems rather to furnish an additional origin to the muscle, which will become a fixed point for muscular action when the tibial band and aponeurosis are tightened by the action of the anterior muscular mass. In the male subjects, Nos. I. and VII., only a short part of the band was left attached to the tibia, and no muscular bundles were noticed.

The longitudinal tibial band being in continuity with the cartilaginous tibia, might be looked on as a fibrous representative of that bone; or, together with the tibial part of the aponeurosis external to it, as representing the hamstring muscles, attached proximally to near the hinder end of the pelvis, distally to below the knee joint.

ON THE STRIDULATING APPARATUS OF *CALLOMYSTAX GAGATA*. By ALFRED C. HADDON, B.A., *Scholar of Christ's College and Demonstrator of Zoology in the University of Cambridge.* (PLATE XX.)

IN dissecting a specimen of *Callomystax gagata*, Ham. Buch., one of the *Siluridæ*, I noticed that the anterior two or three vertebræ were, as is often the case in this group of fishes, anchylosed with each other and with the skull, and that the first intervertebral ligament behind this fusion was thicker than in any succeeding case (Plate XX. fig. 2, *L.I'.*) This immediately suggested that there was more motion at this spot than anywhere else in the vertebral column, such, indeed, was found to be the case; and, on bending the body in a vertical direction, a loud grating sound was most unexpectedly heard. A further dissection showed that—

The large neural spines of the coalesced anterior vertebræ were likewise fused, and were united by an oblique suture with the supra-occipital spine in such a way as to continue the vertical occipital crest a short distance backwards. (Plate XX. figs. 1, 3, *N.S.*) The posterior moiety of this plate of bone was divided into two vertical laminæ, the somewhat produced supero-posterior angles of which were finely crenulated on their *inner* surfaces, there being about thirty parallel vertical rugæ on each (Plate XX. figs. 1, 3, *St.*)

The two anterior interspinous bones were suturally united together, and much enlarged in order to support the strong anterior spine of the dorsal fin, the superior portion of this wedge-shaped bone was finely serrated *on both sides*, so as to form a double file. This interspinous structure lay between the two laminæ above mentioned (Plate XX. figs. 1, 3, *I.S.*)

The action of this mechanism is very simple. The head, with the firmly-united anterior vertebræ and their coalesced neural spines bifid posteriorly, form a rigid structure; the remainder of the vertebral column with its interspinous bones form a more or less flexible structure; but since the intervertebral space between these two structures is greater than any-

where else, the whole vertebral structure will have a tendency to bend upon the rigid anterior structure, and consequently the double file on the first interspinous bone will necessarily scrape against the crenated inner surfaces of the anterior neural spine, and a stridulation will result.

It must be borne in mind that the ordinary natatory movements of the vertebral column do not affect this mechanism, it is only when the body is more or less violently moved in a vertical direction that any sound is produced.

Correllated with this power of producing a distinct sound, we find that this fish, in common with most Siluroids, is provided with an extremely effective auditory apparatus in the shape of a tympanum, which directly receives vibrations from the surrounding medium, and which transmits the same by means of a complicated system of fibres, ligaments, and ossicles to a diverticulum from the vestibule of the internal ear; this tympanum (Plate XX. fig. 1, *Ty.*) being formed by the air-bladder, which is almost entirely surrounded by bone, becoming attached to the very diaphanous external skin.

Unfortunately I have been unable to find any account of the habits of this fish. As a matter of fact, travellers rarely do tell us much about the fishes of other countries except when anything is particularly striking, owing, probably, to the natural difficulties of observation and a general lack of interest in these animals; therefore, as in geology, negative evidence cannot be relied on. Only one specimen has been dissected, and the sex of that was undeterminable. In consequence of this lack of positive information, it would be hazardous to speculate as to whether the noise made by this fish is sexual, protective, or warning.

It is worthy of attention that fish, provided with an accessory auditory apparatus, are known to possess the power of volunarity, or involuntarily making definite sounds; for example, take the case of many (if not all) of the Cyprinoids: the fact of their making breathing and other noises, and of their appreciating sounds, is well known. The so-called tame fish, who come when called, &c., are almost invariably Cyprinoids, but some are Siluroids.

M. Dufossé[1] writes :—" Plusieurs Poissons, et entre autres des

[1] Recherces sur les bruits et les sons expressifs que font entendre les Poissons d'Europe.—*Ann. des Sci. Nat.*, 5th Series, Zool., tome xix. 1874, p. 17.

Cyprinoïdes, des Anguilliformes, et, parmi les Siluroïdes, le Saluth (*Silurus Glanis*, Lin.), font entendre des bruits de cet ordre (les bruits de souffle); mais les plus remarquables sont, sous le rapport des manifestations qu'ils émittent, les Loches de marais (*Cobitis fossilis*, Lin.), les Loches franches (*C. barbatula*, Lin.), les Loches de rivière (*C. Tœnia*), les Barbeaux (*Cyprinus barbatus*, Lin.), les Carpes (*C. Carpio*, Lin.), et les Meuniers (*Cyprinus Dobula*, Lin.)."

Amongst the specialised parallel group, the Siluroids, we also have numerous examples. Thus Dr C. Darwin says:—

"A fish called the 'armado' (a Silurus) is remarkable from a harsh grating noise which it makes when caught by hook and line, and which can be distinctly heard when the fish is beneath the water"—(found in the Rio Parana).—C. Darwin; *A Naturalist's Voyage Round the World* (1879), p. 136.

"Sir Emerson Tennant observed that a Siluroid fish (*Clarias*) found in the lake at Colombo is said by the fishermen to make a grunt under water when disturbed."—Francis Day, Trans. Linn. Socy., "Instincts and Emotions in Fish," Zool., vol. xv. No. 81, March 1880, p. 50.

Dr Francis Day informs us that:—

"Some years since, while stationed at Madras, I obtained several live examples of these fishes (Siluroids), *Macrones vittatus*, termed the Fiddler-fish in Mysore. I touched one which was lying on some wet grass; it became very irate, erecting its armed spines, and emitting a sound resembling the buzzing of a bee, evidently a sign of anger or terror."—F. Day, *l.c.*, p. 45.

M. Dufossé describes how

"The common Siluroid of the Nile,[1] *Synodontis schal*, Schn. (*S. arabi*, C. et V.), as is well known to the natives, makes several kinds of noises; these may be produced in the following manner:—

"1. By the sudden opening of its lips and opercula.

"2. Increased movements either of the articulations of the lower jaw or of its opercula; the noise made by these latter resembles a chattering.

"3. A breathing noise analogous to that of an eructation; this is an irregular noise, and is probably connected with the air-bladder.

[1] M. Dufossé, Recherches sur les bruits et les sons expressifs que font entendre les Poissons d'Europe.—*Ann. des Sci. Nat.*, 5th Series, Zool., tome xx. 1874, p. 117.

"4. A noise made by the movement of the first ray of the dorsal and also of the pectoral fins. Without movement, there is no noise. All the movements of these two rays are not noisy; those of natation are silent, though the rays have their full extent of motion. The movements accompanied by the noise are much shorter, and are often jerky."

It is stated that "when the Herring (*C. harengus*) is just caught in the net and brought to the boat, it utters a shrill cry like a mouse."[1] As Weber[2] first showed, the air-bladder of this fish forms, by means of its anterior bifurcation, an accessory auditory apparatus.[3]

These extracts prove that many (and it will probably be eventually proved that *all*) fish possessing an accessory auditory apparatus, are in the habit of making definite sounds, often when in a state of fear.

But, on the other hand, it must not be overlooked that certain fish can make noises with apparently no further modification of the auditory apparatus than increased size and sensitiveness.

It does not seem unreasonable to suppose that those fish which have the power of producing certain definite sounds also have a higher faculty in the discrimination of sounds than those which are entirely silent, and certainly we must admit this of those fish which do possess an accessory auditory apparatus. This difference being possibly analogous to that observed in the eyes of animals, some eyes only appreciate light and darkness —the so-called "photoscopic" eyes, while others can distinguish definite objects; similarly, some ears may only appreciate noise as opposed to silence—these, we may term, *psophacoustic*;[4] as, for example, the otocysts of the invertebrates and (?) the ordinary piscine ear. While those which can distinguish definite sounds may be termed *phonacoustic*,[5] as in certain specialised Teleosteans and most of the higher vertebrates. It is worthy of notice that most of the phonacoustic fishes also exhibit correspondingly increased tactile sensibility.

[1] J. Murray, *Mag. Nat. Hist.*, iv. 1831, p. 141.

[2] Weber, *De aure et auditu hominis et animalium*, pars 1, Leipzig, 1850.

[3] A careful description of the modified anterior vertebræ and of their connection with the auditory apparatus in the Siluroid, *Malapterurus beninensis*, is given by Prof. Cleland in *Edinb. Phil. Journ.*, vi. N. S., p. 177.

[4] *ψόφος*, noise ; *ἀκούω*, I hear.

[5] *φωνὴ*, articulate sound.

A mechanism, such as the one described above, is not a difficult one to be initiated, since, in the Bream (*C. brama*), the fused neural spines of the first three vertebræ, though not connected with the crest of the Supra-occipital, are bifid posteriorly, and between the laminæ thus formed the squamous first interneural spine is received (Plate XX. fig. 4); also in the Siluroid *Cnidoglanis megastoma*, all the anterior neural spines are bifid for the insertion of the corresponding simple interspinous bones.

EXPLANATION OF PLATE XX.

S.Oc., Supra-occipital crest; *N.S.*, Coalesced anterior neural spines; *St.*, Stridulating apparatus of neural spines; *I.S.*, Enlarged suturally united first two interspinous bones; *I.S.*[3], The third interspinous bone, which, like the succeeding, is free; *Ty.*, Tympanum formed by the outer skin and the air-bladder.

Fig. 1. *Callomystax gagata*, natural size, and partly dissected to show the general arrangement of the structures in question.

Fig. 2. Ventral view of the coalesced anterior vertebræ, showing the imperfect bony floor to the air-bladder (*A.B.*), with its tympanum, and the relative thickness of the first invertebral ligament (*I.L'.*).

Fig. 3. Side view of the stridulating apparatus × 2 diam. *N.S.* points to the line indicating the commencement of the two laminæ.

Fig. 4. Side view of the corresponding parts in the Bream, *Cyprinus brama*.

I am indebted to the kindness of my friend Dr Francis Day for this specimen.

THE STERNUM AS AN INDEX OF SEX AND AGE.

By THOMAS DWIGHT, M.D., Boston, U.S.A., *Instructor in Topographical Anatomy and in Histology at Harvard University.*

I.

IN an essay on the identification of the human skeleton, published in 1878, I called attention to Hyrtl's[1] statement concerning the sexual characters of the breast bone. He says —"I find the difference between the male and female sternum so clearly expressed by the proportion of the manubrium to the body, that it is hardly possible to err in determining the sex. The manubrium of the female sternum exceeds half the length of the body, while the body in the male sternum is, at least, twice as long as the manubrium." I mentioned also Luschka's[2] assertion, that "the body is usually twice as long as the manubrium in woman, and two and one half times as long in man." I gave the results in the essay of the measurements of the sternum in six skeletons, of which the sex was well marked in six dead bodies, and in the life-size figures of median sections of the body in Braune's plates.

Although the mean of these measurements confirmed Hyrtl's law, precisely one-half of the specimens were exceptions to it. My observations, however, were too few to be conclusive, though the number of instances in which Hyrtl's law did not apply was enough to shake confidence in it.

Since then, I have obtained measurements (taken by myself, except in some two or three instances) of the sternum of twenty-seven male and twenty-three female dead bodies. To these I have added the measurements from bodies, which I have already published, suppressing those from skeletons and plates.

The following table accordingly gives the length in centimetres of the manubrium and body of the sternum, in each of thirty men and twenty-six women. An asterisk marks the cases that are in accordance with Hyrtl's law.

[1] *Handbuch der topographischen Anatomie.*

[2] *Die Anatomie des Menschen.*

	Male.		Female.	
	Manubrium.	Body.	Manubrium.	Body.
1	5	10·6*	4·4	9·3
2	6·3	10·1	5	8·8*
3	5·3	10·4	6	7·9*
4	4·9	5·2	5·7	9·1*
5	5·7	10·1	4·7	9·5
6	6·9	9·1	4·4	9·5
7	4·7	11·4*	5	9·8*
8	4·4	11·7*	5	6·6*
9	5	11·4*	4·1	8·8
10	4·4	11*	4·7	9·1*
11	6	11	4·1	7·6*
12	4·7	9·8 *	4·4	8·8
13	5·7	12*	3·6	7·7
14	5·5	11*	4·	8·7
15	5	9	5·1	10·4
16	5	10*	5·4	9 6*
17	4·5	12·7*	5·4	9·6*
18	5·1	10·2*	4·7	8*
19	4·9	11·5*	4·5	9
20	5	12·8*	4·4	9·2
21	4·7	10*	4·5	11
22	5·5	9·1	4·4	8·8
23	5·5	10·3	4·4	9·3
24	7·2	10·1	4·3	10·6
25	4·3	12·5*	4·3	7·8*
26	4·7	11·3*	5	8·1*
27	5·4	9·3		
28	5	14·4*		
29	4·3	10·6		
30	5	9·1		
Mean	5·18	10·59	4·67	8·94

Thus it appears that the manubrium of the male sternum is to the body as 49(−) is to 100, and that in the female the manubrium is to the body as 52(+) is to the 100. Hyrtl's law is thus confirmed for the mean sternum, but unfortunately, not for the individual one. It is to be noticed that it did not apply to twelve of the thirty men, or to fourteen of the twenty-six women. It is certainly of no practical value, and does not justify the assertion that "it is hardly possible to err in determining the sex." Luschka also is quite in error.

II.

Many of the statements concerning the age at which the pieces of the sternum coalesce, are even more wild than those concerning the sex. Mr Hutchinson gives the following account of the matter in his classical article on the thorax, in the *Cyclopædia of Anatomy and Physiology*:—"The lowest or fifth piece is joined to the fourth soon after puberty; the fourth and third are united between twenty and thirty years of age, and the body of the sternum is usually not completed by the junction of the third piece to the second before thirty-five or forty years." He states also that it is only exceptionally, and late in life, that the first piece, *i.e.* the manubrium, joins the second, and that the appendix becomes united to the sternum from the fortieth to the fiftieth year, and even later.

Gray and Holden give the same dates for the joining of the pieces of the body, excepting that they make the fourth join the third between the twentieth and twenty-fifth years.

I am inclined to think that the above statements are adopted from Béclard's views, and copied by one author after another with slight modifications.

According to Wagstaffe, "the lower segments unite after puberty, the upper segments about twenty-five, the body and ensiform in middle age, the body and manubrium in old age." In the eighth edition of Quain, a similar statement is made.

According to Sappey, the two lower pieces of the body unite at from two to three years, sometimes later. He does not give the dates of the union of the other pieces. As for the appendix, he says that its ossification is complete at from thirty to thirty-five or forty years, and that it unites with the body at from fifty to sixty. Both Henle and Cruveilhier place the joining of the first piece of the body with those below it, at from twenty to twenty-five years. Cruveilhier states further, that the appendix joins the body at from forty to fifty years, and sometimes later.

I regret very much that I did not begin to take notes of the ages of the bodies examined till the series of measurements was far advanced, and then I was not always able to obtain definite information. I cannot therefore give statistics of any value; but I feel justified in making a few general statements.

One word as to what "coösified" means. It seems to me to mean that adjoining parts are so firmly connected by bone, that they cannot be separated without breaking or cutting it; but it is by no means necessary that the union should extend through the whole thickness. Thus the sacral vertebræ are said to be coösified, though a section would show spaces between the centres of the bodies. This is mentioned because Cruveilhier speaks of the union between the manubrium and the body being usually only apparent because it is merely superficial. It seems to me none the less real.

My observations have convinced me that the accounts according to which the body of the sternum is in three pieces till twenty or thirty, and in two till thirty-five or forty, are entirely wrong. I can remember but very few instances of persons of twenty or over, in which the body of the sternum was not in one piece.

I can confirm the prevailing idea that the appendix is usually joined to the body earlier than the manubrium is; and I have seen several instances that induce me to think that the appendix is often joined to the body earlier than is generally believed. There is no doubt, however, that there is great variation, and that the sternum is a very uncertain bone. In illustration of this, I quote a few cases from my notes.

The appendix was united to the body in a woman of twenty-two, a man of twenty-three, a male Western Islander of about twenty-eight. The process was beginning in a woman of from thirty-two to thirty-five. The appendix was barely coösified in a man of sixty or more. On the other hand, the process had not begun in a woman of thirty-nine, or in another of fifty or more. A man of about forty, presented commencing ossification between the body and the manubrium, but not between the body and the appendix. Another man, looking at least sixty-five, had the manubrium joined, and the appendix free.

It must be admitted that the breast bone is no trustworthy guide either to the sex or the age.

ON THE MECHANISM OF COSTAL RESPIRATION. By JOHN M. HOBSON, M.D. (With FIGURES).

THE action of the intercostal muscles has attracted the attention of anatomists and physiologists from the time of Haller to the present day, but is still, according to Michael Foster, an open question.

I do not pretend in this paper to settle the question, but I shall offer some observations which, I trust, will help towards that issue.

One view of the action of these muscles is that of Haller and his followers, who maintain that both external and internal intercostals are *inspiratory* muscles. In opposition to this is the theory of Hamberger and his exponent in this country, Hutchinson, namely, that the *externals* are *inspiratory*, while the *internals* are, for the greatest part of their extent, *expiratory* agents. Since the appearance of Hutchinson's article "Thorax," in the *Cyclopædia of Anatomy and Physiology*, English writers have for the most part—till more recent years at least—adopted Hamberger's theory of the action of these muscles. This action, as is well known, is supposed to be illustrated by the model of the parallel bars and elastic bands which is too familiar to need any description.

But Cleland pointed out in this *Journal* in 1867 (vol. i. p. 209), that if this theory were correct, the effective force of either set of muscles must be extremely small, for the contracting band, whether muscular or elastic, pulls equally at both its points of attachment, and the resultant downward or upward movement depends upon greater leverage in the upper or lower rib, or bar respectively.

Supposing the elastic band were attached twice as far from the fulcra at the lower bar as at the upper, twice the force would act upon the former as upon the latter, and the bars would readily go up. But if the difference in leverage were only a small fraction, the effective force would be so little, that a slight stiffness in the joints would be sufficient to stop all movement whatever.

Were Hamberger's model true to nature, this latter condition would, as Cleland points out, obtain; indeed, he demonstrates diagramatically that the effective force would be supplied by only the extreme fibres of each muscle.

Yet this *reductio ad absurdum* is not required to upset the Hamberger theory, for it is only necessary to observe carefully the anatomical facts to arrive at the conclusion that the mechanism of costal respiration is something quite different from the one supposed by that theory.

A little reflection must make it apparent to any one, that in order to understand the working of a machine, one must master not only the details of its construction, but the mechanical relations of it as a whole.

Now it seems to me that writers have, for the most part, not paid sufficient attention to the mechanical relations. Hutchinson, in the article above mentioned, has not only lost sight of the mechanical error of Hamberger, pointed out by Cleland, but has not noticed that the curving of the ribs points to quite a different mechanical arrangement; for though he notices the fact and describes the configuration of the ribs in detail, yet he argues that for the purpose in question, they may be regarded as straight bars.

I think that the necessity of accounting for the forward expansion of the chest has induced writers the more readily to accept Hamberger's theory.

Though, as I have said, English anatomists have much followed Hamberger and Hutchinson, this unanimity has not obtained on the Continent, Baümler, Budge, Henle, and Wundt being among those who agree with Haller, and at the present time differences of opinion exist in our own country.

Cleland points out that the ribs are not at all represented by Hamberger's model, but are curved, and that their main movement is one of rotation round an antero-posterior axis, with its fulcra at the sternal and vertebral joints, although the anterior fulcrum rises and falls a little. Each rib is supported by the one above, and each succeeding arch is wider than the one superimposed to it, so that in taking its place, as it were, in the chest-wall it will make that cavity larger just there.

Humphry (*Br. Med. Jour.*, 1872), while fully recognising with

Cleland the rotation of the ribs on an antero-posterior axis in opposition to that on a transverse one at the vertebræ, according to Hutchinson and Hamberger, does not take into account the obliquity of the axes of the ribs, and speaks of them as horizontal.

Turner states[1] that the internal and external intercostals are both elevators of the ribs.

In vol. x. of this *Journal*, Rutherford describes his experiments on the action of the intercostals. He attaches elastic bands to the ribs themselves in the skeleton. By connecting the bands with the eight upper ribs on each side in a position to represent the external intercostals, he obtained great lateral expansion of the chest, the ribs all rising in the manner indicated by Cleland. At the same time the upper end of the sternum rose a quarter of an inch, and the ensiform cartilage was pushed forward one inch and three quarters. The bands were then placed in the position of the interosseous parts of the internal intercostals in like manner. The ribs were elevated as before, but there was neither elevation nor depression of the sternum, and the ensiform cartilage was moved forward only three quarters of an inch.

It does not appear that the vivisectors have given any unequivocal answer about the action of these muscles.

I think I have quoted enough to show that there is a tendency at the present time, clearly derived from a more careful study of the anatomical facts, to return to the opinion of Haller.

In the following observations I shall give considerable prominence to anatomical facts, and shall endeavour, before saying anything about the muscles, to give a clear representation of the kind of movement taking place in the ribs on which they act.

The problem to be solved, then, is the way in which the bony and cartilaginous walls of the thorax are expanded and contracted in ordinary inspiration and expiration.

To this purpose it will be well, in the first place, to run over the leading anatomical points, in order to bring clearly before the mind the form of the parts concerned in the mechanism of costal respiration, after which I shall dwell more fully on some details which appear to me to have a special bearing on the subject.

[1] *Introduction to Anatomy*, Part I. p. 79, 1875.

The cage-like structure called the "thorax," is built up in front of the anteriorly-concave dorsal spine which forms its foundation, and with which the twenty-four ribs articulate. The seven upper ribs join the sternum in front, which there closes in the thorax, but is much shorter than the dorsal spine, reaching neither so far upwards nor downwards. Behind, all the ribs are articulated with the vertebral bodies, and all, except the last two, with the transverse processes as well, being held to the spine by strong ligaments. In front, the first cartilage is welded with the upper angle of the sternum; the next six are connected with its margin by articulations; the eighth, ninth, and tenth join, each, with the under surface of the cartilage above; whilst the last two cartilages are mere tippings to their respective ribs, and have no anterior attachment.

The ribs are flattened laterally, and take a direction round the contained space; at first backwards and outwards, then forwards and outwards, and finally forwards and inwards, while throughout they maintain a downward direction, except in their anterior or cartilaginous portion, which assumes a different direction for each pair.

The internal surface of the ribs is simply covered by pleura, and thus they help to form a continuously curved surface, which for the most part is in contact with the smoothly gliding lungs within, and takes different directions for different parts of the thorax. Where the chest is rapidly increasing in size, as it is in all directions above, the internal aspect of the ribs is obliquely downwards, whilst lower down, where the increase is less rapid, this obliquity is less marked.

In transverse section, the cavity of the chest is heart-shaped. This is caused by the initial backward inclination of the ribs on either side of the spine. Thus in the median plane the chest is shallowest from before backwards, though, from the curving of the spine and tilting forwards of the lower end of the sternum, it gets deeper from above downwards. The lungs hardly come into this median portion, *i.e.*, between the sternum and the spine, but occupy the two lateral, rudely conical, parts, into which they are moulded.

This point it is of importance to bear in mind, as it it gives a clue to the kind of movement to be expected in the chest-walls.

I have taken a number of measurements in a well-formed male chest, the results of which I shall proceed to give.

I found in my thorax that the first rib inclines very slightly backwards from the head to the tubercle, the second more so, the third still more, and from hence downwards the inclination is about the same for all the ribs from head to tubercle, being greater than from tubercle to angle. The angle is the point where the rib takes a forward direction. The *backward* inclination of the ribs, counting from the third downwards, was 130° from head to tubercle, 120°–125° from tubercle to angle. From tubercle to angle the inclination *downwards* below a horizontal line was 20° for all the ribs.

The following are the angles for all the ribs, formed by their inclination downwards from the horizontal, taken for the remainder of their bony part.

First rib, from tubercle (it has no angle) to the attachment of scalenus anticus, 50°; from thence 30°.

2nd rib, 30°–15°	8th rib, 30°–40°–40°
3rd ,, 30°–10°	9th ,, 30°–35°–35°
4th ,, 30°–10°	10th ,, 30°–40°–30°
5th ,, 30°–10°	11th ,, 40° — 40°
6th ,, 30°–20°	12th ,, 40° — 40°
7th ,, 25°–35° (middle)–30°	

There is thus a remarkable uniformity in the inclination of the ribs. The first six—with the exception of the first, which which is altogether an exceptional rib—all start in their forward direction with an angle of 30°, and gradually decrease in inclination. The next four ribs start with a similar inclination, but acquire a greater obliquity in the middle and never get below their initial angle. Next, as to the inclination and direction of the cartilages. The first three *descended* to the sternum, forming with it angles of 50°, 65°, and 85° respectively. The fourth *ascended*, making an angle at the sternum of 110°, though this was less at the bony part.

The 5th	made an angle at	sternum of	130°
6th	do.	do.	130°
7th	do.	do.	125°
8th	do.	do.	120°
9th	do.	do.	80°
10th, free.			

From the 5th to the 9th the cartilages at first continued the

downward direction of the ribs. The cartilages progressively got longer from 1st to 7th, which was very long, then diminished in length downwards.

Next, as to the maximum width of the thorax between each pair of ribs. The most widely separate points for each pair fall, on either side, nearly into a vertical line. I give not only the maximum width, but the increase in each pair over that immediately above:—

1st,	10·3	c.m.			
2nd,	16·2	„	*increase*	5·9	c.m.
3rd,	21·6	„	„	5·4	„
4th,	24·0	„	„	2·4	„
5th,	25·5	„	„	1·5	„
6th,	26·9	„	„	1·4	„
7th,	27·4	„	„	0·5	„
8th,	27·9	„	„	0·5	„
9th,	28·5	„	„	0·6	„

The measurements of the 10th, 11th, and 12th pairs could not be taken in this case, as, after the removal of the intercostals, these ribs did not retain their position.

From the above it is at once seen that between the first three pairs of ribs the increase in diameter of the chest is very rapid, between the following three decided but considerably less, and between the next three only slight.

I shall now give the measurements of the *axes* of the ribs; by which term I mean the distance between the centre of the head-joint and the centre of the sternal joint. To a *m.m.* or so, more or less, the measurements may not be quite accurate:—

1st,	7·5	c.m.	7th,	8·2	c.m.	
2nd,	10·0	„				Between centre of vertebral joint and middle of connection with cartilage above.
3rd,	8·9	„	8th,	11·5	„	
4th,	9·5	„				
5th,	10·5	„	9th,	11·5	„	
6th,	10·1	„				

The elevation of the vertebral joints above the sternal are as follows:—

1st,	5·1	c.m.	7th,	8·2	c.m.	
2nd,	7·7	„				Taken between centre of vertebral joint and middle of connection with cartilage above.
3rd,	8·9	„	8th,	11·5	„	
4th,	9·5	„				
5th,	10·5	„	9th,	11·5	„	
6th,	10·1	„				

Now, knowing the lengths of the axes and the differences in altitude between their extreme points, we can easily find out the angles of inclination of the axes. These I found in my subject to be as follows:—

1st, 43°	4th, 42°	6th, 42°
2nd, 51°	5th, 43°	7th, 32°
3rd, 46°		

The value of knowing these degrees of inclination we shall presently see.

Any two corresponding ribs (each pair) lie, not in the same plane as their axes, but below them. This I have proved by direct observation, but it is what must be the case when we consider the fact that each rib *descends* through its whole course. Thus, to be at the commencement of its course in the same plane as the axes belonging to that pair, a rib would have at first to *ascend* in passing backwards, while in fact it *descends*, and thus puts itself more and more below that plane till the angle is reached. Again, for a rib to get up to the level of the plane of the axes, it would have to reduce the angle of its inclination and again increase it in order to hit the sternal joint, as one may say; but though the inclination does diminish, in none is it again increased. Moreover, from the 4th rib downwards the cartilages bend up to the sternum.

So much for the anatomical statement with regard to the ribs. What are the movements which they execute in respiration, and what effect have such movements on the shape and capacity of the chest?

In a recently cleaned thorax, *i.e.*, where the viscera, muscles, and pleura had been removed and there had not been time for drying to interfere with the mobility of the ribs, I found the following:—

The only free movement produced in a rib by making upward pressure upon it near the sternum, was rotation upwards round an antero-posterior axis. As to the relative mobility of the ribs, that of the first was very slight (true its cartilage was partly ossified), then it rapidly increased to the fourth, from thence to the ninth the mobility was much less, while the tenth, eleventh, and twelfth were freely movable, having no anterior attachment. All, except the last three, were perfectly resilient, *i.e.*,

they returned to their former position when the pressure which pushed them up was relaxed.

If we were to place a geographical globe on the table before us, so that the north pole lay nearest our right hand and the south nearest our left, and one meridian divided the hemisphere which faced us, equally; then, as the other meridians were farther to the east of this one, they would seem more curved, thus representing the position of the ribs during rest. If, now, the globe were rotated to the west, the meridian marked next to the east would replace the first meridian. Take any point on this meridian and note in what direction it would be rotated.

1. It would move to the west, *i.e.*, nearer our left hand. 2. It would be carried to a greater distance above the table. 3. It would come nearer to us. This would be true for every point along that meridian, and the proportionate movement in each of these directions would remain the same for each, only that farthest from the poles would move most. In fact, each point travels along either the equator or a zone parallel to it.

So it is with a rib. The axis corresponds to the axis of the globe, and the position of the rib in rest is analogous to that of the meridian which travelled, while each point on the rib would, in rotation upwards, pass along a path corresponding to the equator of a globe. There would only be this difference, that, whereas in our meridian each point lay on the equator, or on a line parallel to it, in the rib each point has its position on the equator of an imaginary sphere rotating with every other sphere round a common axis. Thus each point in the rib rotates round the common axis at its own distance from it, and traverses a path strictly parallel to that of its fellows. For each rib the direction of rotation is away from the median plane, and, at the same time, upwards and forwards. The inclination forwards of its path will bear a constant relation to the inclination of the axis, and will be indicated by a straight line at right angles to it. If we know the angle of inclination of the axis of a rib, we can readily tell the forward inclination of every point on that rib during rotation. Thus the axis of the second rib has an inclination with the *horizontal* of 51°, hence a line drawn at 51° with the *vertical* will indicate the direction of its path of rotation. This is at once seen by reference to the accompanying figure.

So much for the movements we should expect a rib to execute from consideration of its anatomical features and mechanical relations. The next question is, "What effect would such movements have on the shape and capacity of the chest?"

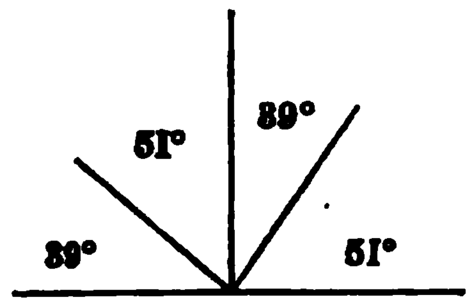

Fig. 1.

Inasmuch as every point on a rib is moved farther away from the median line during inspiration, we have therein an *element of expansion*, but it will not do to jump at once to the conclusion that there is on that account an actual increase in the transverse measurement in every direction. The accompanying figure is a tracing of the upper and inner border of the third rib and cartilage reduced to *one-fourth*. S. is the sternal and V. the vertebral end; all in front of the dotted line, *i.e.* from A. to S., looks forwards, all from A. to V. looks backwards. Take the widest point A, situated between the anterior and posterior segments of the chest: it moves upwards, forwards, and *outwards;* in its new position it does not replace any other point in the chest-wall, for there was none so external, at that height, as it is now, or, one might say, there was no point *behind* where it now is when the chest was at rest.

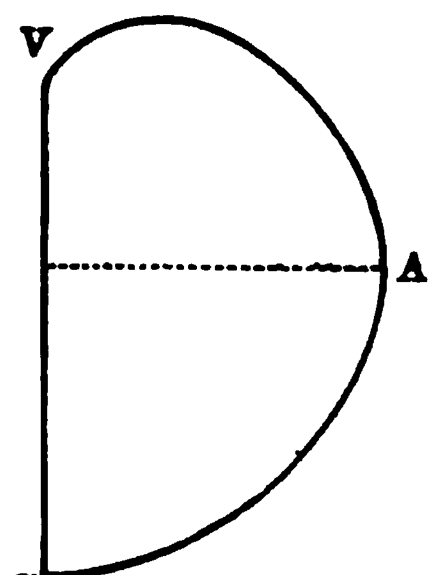

Fig. 2.

The same happens for a short distance along the rib in front of the widest part. But for the rest of the rib in front, as far as the sternal joint, any point in rotating will pass similarly upwards, forwards, and *outwards* till it comes to take up a new position as high as some former point which was there at expiration. But it will become more forward than that point, for three reasons.

1. Any point in the anterior segment of the chest-wall which is more external is also more posterior.

2. Each rib projects farther forwards, as low as the seventh at any rate, than the one above it.

3. The moving point is more anterior than it was before.

Thus we are led up to the conclusion that the anterior segment of the chest is enlarged by the walls coming more forward, extending more outward, and by their *inward sloping* becoming less. This is seen in the diagram A.

Next take the posterior segment of the chest. From A (fig. 2) to a point a little backwards, rotation upwards, forwards, and outwards will bring that portion of the rib *behind* no former position of any part of the chest-wall, for there was none so external during expiration. From thence to the vertebral joint each point will be carried in rotating into correspondence with one more external. If this higher and more external point were in each case more anterior than the new position of the rib, then space would be gained by the posterior segment of the chest being carried, as a whole, more backwards.

Inasmuch as the point *pursued*, as we may say, was anterior to the pursuing one during rest, especially in the upper ribs, it is most probable that the first is nowhere overtaken by the second, but that there is everywhere an increment in the antero-

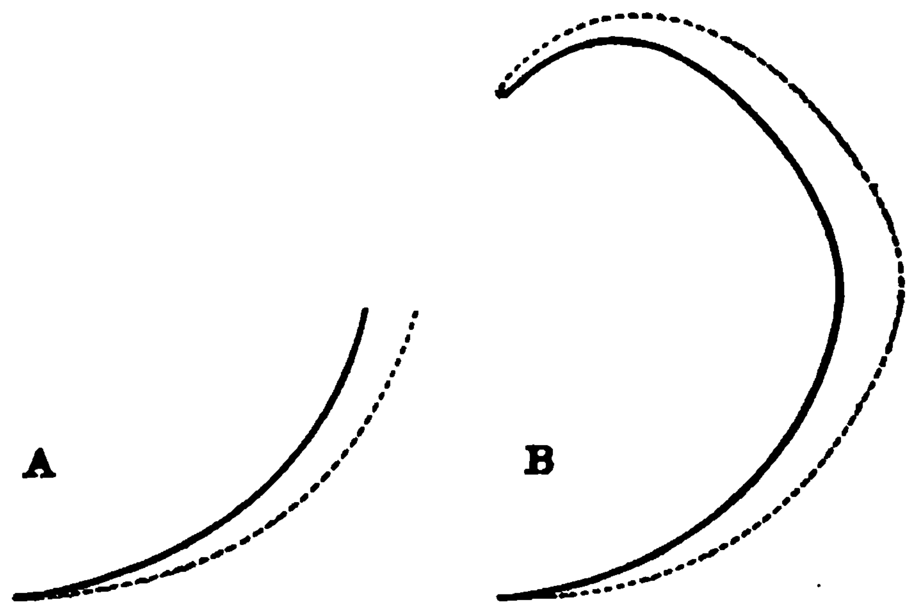

Fig. 3.

posterior direction. Hence the posterior segment of the chest is enlarged in an exactly similar manner to the anterior, only backward is substituted for forward expansion. The circumference of the chest, then, is enlarged in the manner indicated by the diagram B.

Having learned in what manner the framework of the chest-walls is moved, and how that movement conduces to the expansion of the chest in inspiration, it follows to inquire what are the agents in rotation of the ribs.

I think there is little doubt that the muscles, which are constantly brought into play, are the internal and external intercostals, and the levatores costarum. That both sets of intercostals are agents in inspiration is to be expected, for two reasons :—

1. Their position indicates at once that they have no other office than that of acting on the ribs.

2 There is no necessity for muscles of ordinary expiration, as the resiliency of the ribs and of the lungs is quite sufficient to restore equilibrium after the inspiratory effort. In fact, the lungs alone are sufficient for that purpose, for Dr Douglas Power has shown that the recoil of the lungs actually leads to a drawing in of the chest-walls to a small extent, from which their own resiliency frees them when an opening is made in the chest after death (*Br. Med. Jour.*, 1879). Why, then, should we expect to find muscles for use only on rare occasions when unusual—mostly pathological—conditions call for their aid?

Then, as for the levatores costarum: They are really external intercostals attached above to the tip of a transverse process, while the immediately adjacent intercostal has its origin from the adjoining portion of rib, runs in the same direction, and is closely applied to it. The levatores are attached above, as I have said, to the apices of the transverse processes, and expanding as their fibres pass downwards, outwards, and backwards, are inserted into the ribs below between the tubercles and angles. There is one to each rib. The external intercostals are attached to a rib above, and their fibres pass downwards and forwards to the rib below to be inserted *from* the angle—or a little internal to it, running then beneath the levator—*to* a varying distance—½ to 1¾ inch—from the end of the bony rib. The muscle is of considerable thickness behind, and steadily thins towards the front, where it is very thin. Here is a note which I made with reference to the muscle:—"As far as the fifth intercostal, those fibres which are inserted at the angle are thickest; in the sixth interspace, those a little in front of the angle are thickest; so also in the seventh, eighth, and ninth. The tenth and eleventh muscles are of about equal thickness throughout."

The internal intercostals are deeper than the externals. Their attachments commence at or near the sternal joint, and reach to or within the angle. The direction of their fibres is downwards and backwards, but generally with less obliquity than the externals. I have made the following note of their thickness in my specimen:—"In the first four spaces the part between the cartilages is distinctly the thickest, while the most posterior is thinnest [very thin]. In the fifth, sixth, seventh, and eighth,

there appears no decided difference throughout. In the ninth, tenth, and eleventh again, the anterior is the thickest and posterior thinnest."

If now we consider the position of these three sets of muscles, the levatores, the internal, and external intercostals, it will become apparent that the action of each will contribute towards the rotation of the rib in the direction we have seen. Let AB (fig. 4) represent a rib, and CD the direction of its rotation.

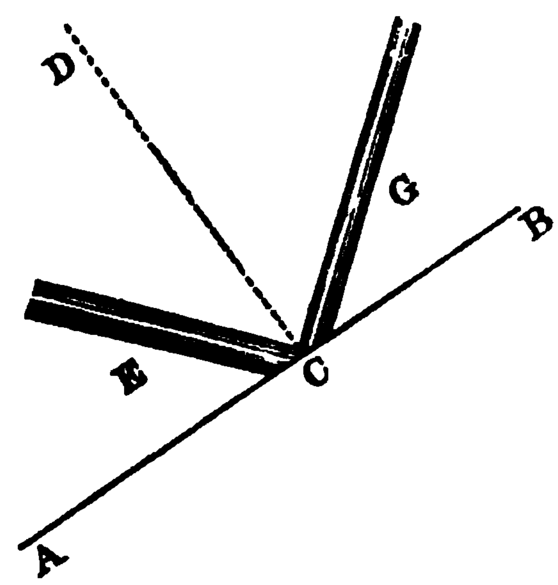

Fig. 4.

It appears that a muscle G, representing an external intercostal, could, by its contraction, move the point C in the direction CD, it being only free to move in that direction. The same can be said for a muscle, E representing an internal intercostal. Some arrangement like that in the diagram does actually exist in most parts of an intercostal space, *i.e.*, on any one point on a rib an external and internal bundle of muscular fibres do meet at an angle.

It is easy enough to complete the *parallelogram of forces* in such a diagram as this, and show what share in the work each muscle might take in the movement. Take a case in point. In

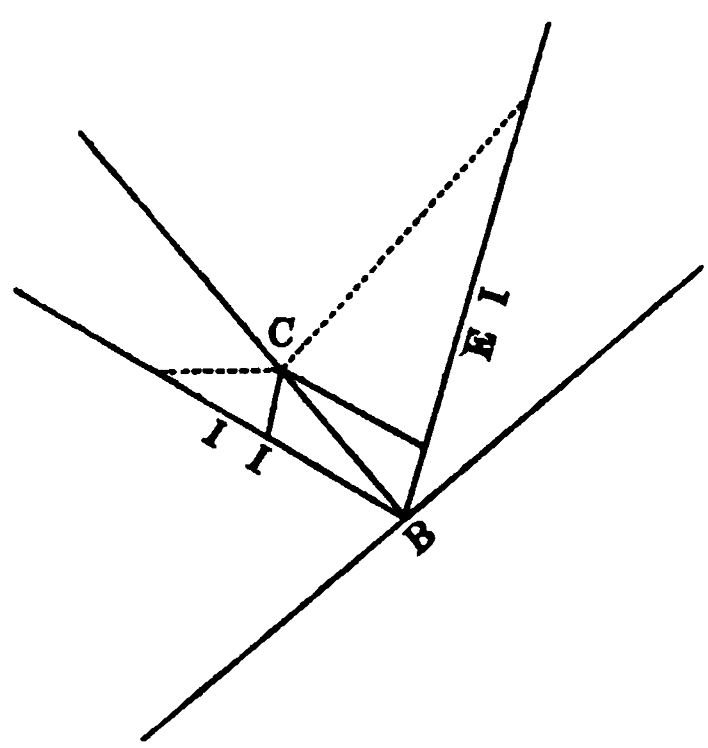

Fig. 5.—B, rib or its axis; E I, external intercostal; I I, internal intercostal.

the fourth space at one point I found the internal to make an angle with the horizontal of 30°, the external an angle of 70°. The inclination of the axis of the fifth rib is 43°, the muscles were here of equal thickness, and their lengths 1·8 c.m. and 2·7 c.m. respectively. Supposing the point B on the rib to be moved along the path of rotation as far as C, a distance of 1·2 c.m.; the internal has contracted 1·1 c.m., while the external intercostal has only contracted 0·4 c.m., and the proportion of strain thrown upon them is as 1·05 to 0·45. This seems a very

unequal distribution of labour, but it is impossible to represent the exact state of things by such means, as the internal and external fibres are not so distributed that they will admit of its being done so simply. For, as we have seen, the internal are well developed where the external intercostals are feebly represented or absent, and *vice versa.*

Most probably the distribution of work is really equal, and the aggregation of muscular fibres is adjusted to the resistance to be overcome at different parts. At the centre of the rib the muscles are placed at the end of a long lever of the second order, and would not meet, were they the only muscles present, with so much strain as at either end of the rib. Whether there are fewer fibres or not inserted at the centre than elsewhere, it does not matter, as, if there were fewer, more strain would be thrown upon those more remote, if an equal number, less, and if more fibres then still less at the extremities. Again, in my diagram, the internal receives an undue share of work, but if there were two internals to the one external acting on the same point that irregularity would be removed. In the case in point, the muscles were equally thick, but more fibres of the internal were inserted into an equal area, because of their less obliquity with regard to the rib; or if the extra internal fibres were carried to another part of the rib, their compensatory action would be still effective. Then, again, the compensation might be effected through there being extra external fibres inserted either at the same spot or elsewhere on the rib. Thus we can understand how an adjustment of the fibres may exist though it would be very difficult, if not impossible, to demonstrate. There remain now only a few more points in the mechanism of respiration, as studied from a purely structural aspect, that require consideration.

I have regarded throughout these remarks the rib and its cartilage as moving *en masse* in respiration. My reason for so doing is twofold:—1. To simplify the argument. If there is any movement between the rib and cartilage, it is secondary to the general movement. 2. In the first three ribs the bone and cartilage are in one line or nearly so, and therefore the opening of the angle between them, which is spoken of in books, does not take place in their case. As for the other ribs, I think there is no anatomical evidence that any movement between

the two parts of the ribs takes place. (*a*) There is no joint between them. (*b*) The cartilage is merely an unossified part of the rib, which, as life advances, may become more or less impregnated with earthy salts.

If, however, any movement between the bony and cartilaginous parts of the rib takes place, it, no doubt, is of the nature referred to, viz., an opening out of the angle between them, effected by the contraction of that portion of the internal intercostal placed between the adjacent cartilages, and would, perhaps, precede the general rotation of the entire rib. The result of this would be, either that the end of the bony part would be more widely separated from the sternum, or that the sternum itself would be pushed forwards. Now, I think that there is no provision for the rib to be thus thrust backwards and outwards, because the transverse process would prevent any backward movement of the tubercle, while the interosseous ligament would check any forward tilting of the head, and one or other of these movements would take place. So it would have to be the sternum which moved forwards, and this might be possible with combined action in the fourth, fifth, and sixth spaces. But the desirability of such a movement of the sternum, especially at its lower half, seems doubtful, seeing that the heart lies between it and the spine here, and hardly any lung. True, the late Dr Sibson, writing on the "Movements of Respiration in Disease," in the *Pathological Transactions*, some years ago, described them in healthy subjects, and found a forward motion of the sternum; but as his recording instrument required the subject to lie between a plate at one end and a moving button at the other, we should expect the posterior wall of his chest swelling backwards in the manner I have described, that his body would be thrust upwards *en masse*, and the button pushed up with it, so that this could not imply an independent movement of the sternum. Indeed, another writer (Baümler, *Syd. Soc. Yr. Bk.*, 1862), has observed that the sternum does not move forward in ordinary inspiration.

Now as to fixed points and order of movement.

One cannot say from mere anatomical consideration whether or not the scaleni act as ordinary muscles of inspiration, but I should deem it highly probable, from the necessity for fixation

of the first rib, that their contraction was the first step in the inspiratory act.

Thus, the first rib, and with it the sternum, being fixed, the intercostals and levator costæ of the first *interspace* would begin to elevate the second *rib*, and make it fixed for the muscles of the second *interspace*, and so on throughout all the spaces.

This implies a wave of muscular contraction from the root of the neck to the lower part of the thorax, as, indeed, is probably the case, seeing that those muscles nearest the medulla oblongata would be reached by a general stimulus proceeding from the respiratory centre sooner than those farther from it.

There is one point more, and that is the reversal of the mechanism.

In health we need in general no expiratory muscles acting directly on the ribs. Sneezing and coughing are accomplished by the more rapid action of the abdominal muscles; but in emphysema expiration is difficult, and cannot be hastened by violent spasmodic contractions; yet a reversal of the ordinary inspiratory mechanism could help to effect it. After the inspiratory effort, the quadratus lomborum could fix the twelfth rib and other muscles, such as the serratus posticus inferior and sacrolumbalis, would help the intercostals in rotating downwards the ribs.

THE MEMBRANA PROPRIA OF THE MAMMARY GLAND. By C. W. MANSELL MOULLIN, M.A. MD., Oxon., F.R.C.S., *Fellow of Pemb. Coll., Oxford* (with Figures).

AMONG the elements contributing to the structure of the terminal acini of the mammary gland, there is generally stated to be a basement membrane, from the clear delicate line that may be seen in microscopic sections outside the epithelium; but its consistence is so fragile and opportunities for demonstrating its texture are so rare, at least so far as the human breast is concerned, that although it is admitted that in all probability there is no material difference in structure between it and those found in similar glands, this is rather a matter of inference than otherwise.

Langer, in Stricker's *Handbook*, considers it to consist of reticular connective tissue, the cells of which, surrounding the acinus, form a meshwork, easily seen after the epithelium has been detached, with nuclei situated at the nodal points; but he admits that he has not been able to demonstrate either the relation between the cell-processes and the epithelium on their inner surface, or that between the cells themselves and the apparently structureless membrane, the presence of which may be demonstrated by maceration. This latter point has been, I think, satisfactorily cleared up in the microscopic examination of a tumour of the breast that recently came under my notice. Its structure may be very briefly summarised as a diffuse fibroma of the gland with everywhere throughout it cystic degeneration of the acini, the change being general, not limited to any portion. As the connective tissue grew in between the acini of a lobule the epithelium in the interior began to proliferate and change its character, while the cavity rapidly expanded; so that soon the cut section of tumour lost all resemblance to normal breast structure, and consisted of nothing but fibrous tissue studded in every direction with minute cysts. Every stage in the development of a single acinus into a cyst was traced many times over.

As the expansion of the acinus began, on its outer surface, where the epithelium had been detached, could be detected faintly marked nuclei, surrounded by small masses of granular

cell substance, irregular in shape and indefinite in outline, but more clearly limited in the neighbourhood of the nuclei than elsewhere. Later, when the cyst was fully formed, and the epithelium instead of being columnar had become squamous, the edges of these ill-defined masses became more clear, so that they appeared like stellate cells, with three or four processes crossing each other irregularly in all directions, well marked where they sprung from the cell, but fading away towards the tips. Later still the star shape changed to that of long spindle cells, each cyst being surrounded by parallel rows of long tapering cell-like bodies ranged side by side, with the greatest regularity, and fitting in between each other, but not nearly touching. For filling in all the space between them and connecting them together, was a delicate almost hyaline membrane, staining with difficulty, capable of being detached in long strips, as distinct from the connective tissue on its outer surface as from the epithelium on its inner. The spindle-shaped cells were situated in the substance of this membrane, of which they must be regarded as mere thickenings, projecting in relief on either surface, so that when cut across obliquely, their cut ends being stouter, projected beyond the line of section of the intervening structure. Their outline, which was well marked only in the neighbourhood of the nucleus, where they were thickest, was, so far as the rest was concerned, ill-defined and granular, and they could not be isolated even for the shortest distance from the membrane between them, at least after hardening in alcohol or chromic acid; so much so that, as in the membrana propria of the lacrymal gland, they may be fairly well compared with the ribs on a leaf or the toes of a webbed foot.

Of course this extreme development can only be regarded as a pathological caricature, coincident with the alteration taking place in the acini; but it seems to me there can be little doubt from it, that in the normal mammary gland the membrana propria is exactly similar to that which Franz Boll has described for the lacrymal one—delicate stellate, cell-like thickenings, with nuclei situated in the substance of a continuous hyaline membrane. At least this must be regarded as a singular example of how the pathological histology of an organ may illustrate the normal.

A, B, Segments of two small cysts showing the structure of the membrana propria which has become the cyst-wall. The greater part of the epithelium in each has been detached.

ON DOUBLE AND TREBLE STAINING OF MICROSCOPIC SPECIMENS.

By WILLIAM STIRLING, M.D., Sc.D., F.R.S.E., *Regius Professor of the Institutes of Medicine in the University of Aberdeen.*

THE attention of histologists has been directed to the value of the double or treble staining of microscopic preparations. By using dyes of two different colours, it is possible to differentiate more clearly certain parts of a microscopic section of an organ. This process is of the greatest value, and can be employed with excellent results even by students. I have used various methods for the last three years, and I propose to state shortly those combinations of colours which I have found to be most useful for class purposes, and also to mention for what organs each combination is best suited.

A solution of picro-carmine, as recommended by Ranvier, is found to be one of the most useful dyes that one can employ. Schiefferdecker in 1878 proposed to use an alcholic solution of eosin as a ground colour, and to stain the sections afterwards with methyl-violet or dahlia. The two latter are aniline dyes.

OSMIC ACID AND PICRO-CARMINE.

Blood of a Newt or Frog.—Mix a drop of blood with a drop of a one per cent. aqueous solution of osmic acid, and allow the slide to stand. This "fixes" the corpuscles without altering their shape. At the end of five minutes remove the excess of osmic acid with blotting-paper, add a drop of solution of picro-carmine and a trace of glycerine to prevent evaporation, and set aside for three or four hours (or even longer, as no over-staining takes place). At the end of this time the preparation is examined. The nucleus will now be found to be stained red, and the perinuclear part homogeneous and yellow. If a drop of blood (taken from a frog which has been kept through the winter) be prepared by this method, some of the corpuscles may show "vacuoles" in the perinuclear part.

Epithelial Cells.—If epithelial cells of any kind are first subjected to the action of a solution of osmic acid so as to "fix" their propoplasm, they may be stained by prolonged immersion in picro-carmine.

Picric Acid and Picro-carmine.

Blood of a Newt or Frog.—Place a drop of blood on a slide, and add a drop of a saturated solution of picric acid, put the slide aside and allow it to remain for five minutes, and at the end of that time when the acid has "fixed" the corpuscles (that is, has coagulated their contents), the excess of acid should be removed by means of a narrow slip of blotting-paper. A drop of a solution of picro-carmine should now be added, and a trace of glycerine to prevent evaporation, and the preparation set aside for an hour. At the end of that time remove the picro-carmine solution by means of a slip of blotting-paper, and add a drop of Farrant's solution or glycerine, and apply a cover. The preparation may then be examined, when the perinuclear part of some of the corpuscles will be seen to be highly granular and of a deep yellow colour, while the nucleus is stained red. In some of the corpuscles there may also be seen delicate yellow-coloured threads, extending from the nucleus to the envelopes. In others the perinuclear part remains uniformly homogeneous. This and the above preparation of blood corpuscles can be preserved in glycerine. I have specimens which have retained their beauty for three years.

Yellow Elastic Tissue.—Longitudinal and transverse sections of the ligamentum nuchæ of an ox are stained with picro-carmine. The elastic fibres are stained yellow, while the small amount of connective tissue between the elastic fibres becomes red.

Yellow Fibro-Cartilage.—Harden a piece of the epiglottis of an ox for twenty-four hours in a saturated watery solution of picric acid; make sections, and stain them with picro-carmine. All the connective tissue and the nuclei of the cells of the mucous glands which exist in its mucous covering are stained red. The perichondrium of the cartilage is stained red. The elastic fibres are stained of a deep yellow, while the nuclei of the cartilage corpuscles are stained red. One can trace the elastic fibres of the cartilage passing into the yellow elastic fibres of the perichondrium. These preparations, like all picro-carmine preparations, improve after a few days. Nuclei become stained that were not visible at first. These preparations ought to be mounted in Farrant's solution or in glycerine. Care must

be taken not to wash the sections too much after they have been stained else all the picric acid will be removed.

Fœtal Bone.—Fœtal bone which has been decalcified in a saturated watery solution of picric acid forms a most suitable preparation for picro-carmine. After a few days all the connective tissue and the bone corpuscles are red, while the bone matrix is yellow.

The Aorta.—Harden the aorta in picric acid for twenty-four hours; make sections, and stain them with picro-carmine; mount them in Farrant's solution. All the connective tissue is red, all the elastic fibres yellow, but in the middle coat faint yellowish-brown coloured patches are clearly distinguishable from the elastic fibres or plates and the red connective tissue; this is non-striped muscle, so that in reality one obtains a treble stain.

PICRO-CARMINE AND LOGWOOD.

Stain the sections first with picro-carmine, and after staining wash them in water slightly acidulated with acetic acid. Stain them with *dilute logwood* solution till they assume a lilac tint. Wash them and mount them in glycerine or dammar; the great point is to avoid overstaining the sections with the logwood. This method does very well for skin, scalp, developing bone, and the non-striped muscular fibres of the mesentery of the newt.

PICRO-CARMINE AND AN ANILINE DYE.

I have tried a great variety of the aniline dyes, but in my opinion none of them is so good, at least for gland tissue, as iodine green. It is used in the form of a one per cent. watery solution. Stain the tissue in picro-carmine; wash it in water acidulated with acetic acid, and then stain it in a solution of iodine green. This solution stains rapidly, and care must be taken not to over-stain the tissue. Rapidly wash the section in water, *and mount it in dammar.* Do not leave the section too long in spirit before clearing it with clove oil, because the spirit dissolves the green dye. I have preserved specimens doubly stained in this way for many months. I find students succeed in doing the process with the best results. Few methods yield such good results and are so instructive for the purpose of teaching. All preparations stained with iodine green must be mounted in dammar.

Wherever adenoid tissue and mucous glands exist this process is applicable. These structures are stained of a bright green.

Picro-carmine and Iodine Green.

Fœtal Cancellous Bone.—Stain a section of the cancellated head of a fœtal bone in picro-carmine, and after washing it as directed above, stain it with iodine-green and mount it in dammar. All the newly-formed bone is red, but in the centre of each of the osseous trabeculæ the residue of the calcified cartilage on which bone is deposited is stained green. No method that I know differentiates so clearly this marked difference in the constitution of these trabeculæ. Many of the bone corpuscles are stained green.

Ossifying Articular Cartilage.—Make vertical sections through the cartilage and subjacent bone where the epiphysis is united to the shaft, but where the line of ossification still exists. Stain them first with picro-carmine and then with iodine green. The articular cartilage becomes green, and so do the remains of the calcified cartilage trabeculæ on which the new bone is deposited.

Posterior part of the Tongue.—In the posterior part of the tongue *two* kinds of glands occur, the *mucous glands* (Weber) and the *serous glands* (v. Ebner). These are quite different in structure and function. The mucous glands secrete mucin, and their alveoli are lined by moderately tall columnar epithelium, which is usually quite clear. The nuclei of these cells are always small, and lie near the attached end of the cell. The clear appearance of these gland cells is due to the presence of mucigen, which distends and fills the meshes of the intra-cellular plexus of fibrils which occurs within these cells. These gland alveoli are stained green. The epithelium of the alveoli of a serous gland is always somewhat granular and turbid, and closely resembles the submaxillary gland of a rabbit in structure. The alveoli are not affected by the green dye, though they are stained with carmine or logwood. It is therefore very easy to get a student to appreciate the marked difference in colour. The ducts of these serous glands usually open at the base of the papillæ foliatæ, which are so admirably developed in the rabbit's tongue. All the adenoid tissue, which occurs in small oval masses in the mucous membrane of the posterior part of the tongue, is stained green. In a section of the posterior part of a human tongue, it is quite easy, after double staining, to observe with the naked

eye the mucous glands and adenoid tissue, because of their green colour.

Peyer's Patch.—Harden a piece of the small intestine of a dog or cat in a mixture of two parts of a sixth per cent. solution of chromic acid and one part of methylated spirit. After two weeks, make transverse sections from a piece of the intestine which contains a Peyer's patch; stain a section with picro-carmine and then with iodine green. One gets in reality a treble stain. All the adenoid tissue and mucous glands are green, the connective tissue bright red, and the muscularis mucosæ is light brown. Each kind of tissue, therefore, occurring in the wall of the gut is distinctly mapped out by this variety in the coloration. These are most instructive preparations.

Solitary Glands.—Do the same with the solitary glands of the large intestine.

Trachea.—Make a transverse section of a properly hardened trachea. All the mucous glands and the cartilages are stained green, the connective tissue red, and the trachealis muscle of a yellowish brown.

Bronchus.—This, when double stained like the trachea, shows the same variety in colour.

Skin.—Double stain a vertical section of the skin, preferably from the sole of the foot of a fœtus. The cuticle and superficial layers of the epithelium are yellow, the stratum (rete) Malpighii is green, and one sees most admirably the continuation of these cells into the ducts of the sweat glands, which are themselves green, and form a marked contrast to the red-stained connective tissue of the cutis vera, through which they have to ascend to reach the surface.

The Cerebellum, when double stained, is a most instructive object. The outer layer of the grey matter, with Purkinje's cells, is red, while the inner or granular layer is green.

LOGWOOD AND AN ANILINE DYE (Iodine green).

Logwood may be used as the ground colour, but care must be taken not to stain the sections too deeply. They may then be stained with iodine green. This combination does best for the mucous glands of the tongue (green), while the serous glands take on the logwood stain.

Eosin and Iodine Green.

Eosin is used as the ground colour. Stain the tissue in an alcoholic solution of eosin, which will stain it very rapidly, usually in a few seconds. Wash the section thoroughly in water, acidulated with acetic or hydrochloric acid (1 per cent.), and then stain it with iodine green. This combination does very well for developing bone, and for the cerebellum.

Eosin and Logwood.

Here, again, eosin is the fundamental or ground colour. This combination does very well for the cerebrum. The general substance of the cerebrum becomes stained with the eosin, while the logwood gives the nerve cells a lilac or logwood tinge.

Gold Chloride and an Aniline Dye.

Dr Heneage Gibbes has recently directed attention to the value of this combination, especially for growing bone, and I can fully corroborate his statements. The tissue to be stained must first be impregnated with gold chloride, and after this is reduced it must be stained with an aniline dye, either aniline blue, iodine green, or a red dye such as rosein. The tail of a young rat, containing, as it does, so many different structures, is an excellent material.

Tail of a young Rat.—Remove the skin from the tail, and place pieces of the tail, one inch long, into the juice of a fresh lemon for five minutes, and afterwards wash them to get rid of the acid. The fine tendons swell up under the action of the lemon juice, and thus permit the more ready access of the gold chloride. Place the tissue for an hour or an hour and a half in a one per cent. solution of gold chloride. Remove it and wash it thoroughly, and place it in a 25 per cent. solution of formic acid for twenty-four hours, which reduces the gold. During the process of reduction the tissue must be kept in the dark. The osseous tissue has then to be decalcified in the ordinary way with a mixture of chromic acid and nitric acid. After it is decalcified preserve the tissue in alcohol. Transverse sections of the decalcified tail are made, and they may be stained with a red dye, such as an alcoholic solution of rosein, and afterwards with a watery solution of iodine green; mount them in dammar.

ON THE COMPARATIVE ANATOMY OF THE LYMPHATICS OF THE MAMMALIAN URINARY BLADDER. By George Hoggan, M.B. (Edin.), and Frances Elizabeth Hoggan, M.D. (Zurich), M.K.Q.C.P. (Ireland.) (Plate XXI.)

In the bodies of the higher animals, the urinary bladder presents the unique example of an organ of the nature of a reservoir, whose special function seems to be that of retaining, for a considerable time within the body, a substance of a purely excretory nature, noxious and poisonous in its action, whether that be regarded in its local effects following extravasation into the tissues, and causing gangrene or death of these tissues, or in its general effects by non-elimination from or re-absorption into the system, leading to coma and death of the individual.

That such an organ should stand in a special relation to the whole function of absorption, whether that be performed by the bloodvessels or the lymphatics, must be evident to every one, and we might expect that in it, absorption would be either non-existent, or at least at its minimum force. Naturally enough, the very name of absorbents, so unfortunately applied to the lymphatics, would equally lead one to infer that that system of vessels was either unrepresented there, or found only to an extremely limited extent. These two inferences regarding structure and function do indeed represent, as far as we can discover, almost all the opinions which have been held, in the absence of exact facts connected with the bladder, ever since the discovery of the lymphatics, or the miscalled absorbent vessels.

Even at the present day it may justly be affirmed that nothing definite is known of the lymphatics of the bladder. If we consult our English anatomical text-books, we find the whole question dismissed in a few words. The editors of Quain's *Anatomy*, 8th edition, tell us, page 512: "The *lymphatics of the bladder*, taking rise from the entire surface of that organ, enter the glands placed near the internal iliac artery." Brief and vague though may be the information thus given, it

is entirely erroneous, more so perhaps than the opinion recorded by Cruveilhier in 1852, at page 586 of his *Anatomie Descriptive*, where it is stated that "the lymphatics come from two sources: (1) from the mucous membrane, whose lymphatic plexus may be injected with the greatest facility (*sic*); (2) from the peritoneum." According to Sappey in his *Anatomie Descriptive*, vol. ii. 1876, page 856.

"The lymphatics of the bladder were first referred to by Zeller, first described by Cruickshanks, and represented by Mascagni; according to the latter two authors, they were even very numerous."

But, as Sappey very justly remarks,

"They were much more fortunate than all subsequent observers, for, since the publication of Mascagni's great work, no author has ever succeeded in finding these lymphatics. Surprised at this negative result, I have explored in my turn the two surfaces of the bladder, particularly the internal surface, at every point, and always without success. It would therefore appear to be destitute of this system of vessels; no facts at least demonstrate their existence."

He also states positively that

"The lymphatic vessels of the mucous membranes of the bladder and uterus have never been injected;"

and this statement, in opposition to that of Cruveilhier, is rendered very probable by the condition of the lymphatics in that locality. Further on he says:

"We may, however, observe on the external surface of the bladder, two or three absorbents on each side. These are the trunks which were seen by Cruickshanks and by Mascagni, but they do not come from the wall of the bladder, but from the prostate, and I believe that I have been the first to inject them."

It is interesting to note that this opinion of Sappey's, although we cannot confirm it, agrees perfectly with the results obtained from the very latest physiological experiments undertaken for the purpose of testing the comparative absorbent power of the different parts of the urinary tract.

As Professor Sappey is one of the most accomplished living anatomists, and has obtained great repute for his personal investigations into the lymphatic system, and written its most recent history, it may be well to conclude our review of the results obtained hitherto, by quoting from his recent work,

Les Vaisseaux Lymphatiques, published in 1874. At page 9, speaking of the lymphatics of smooth mucous surfaces, he says:

"Amongst the mucous membranes belonging to this group, there are several which are absolutely and constantly destitute of lymphatic vessels; such as the mucous membranes of the bladder, and ureters of man, and the mammalia in general. In vain have I explored the mucous membrane of the whole urinary tract in men and women, in infants, adults and old people, varying in a thousand ways the reagents proper for this investigation; the result of all my observations has been completely negative, and as there does not exist in the annals of science any fact attesting that other observers have been more fortunate than I have been, we must admit that nothing demonstrates the presence of these vessels in the mucous membrane of the urinary tract, and that very probably they do not exist."

The opinions we have quoted may possibly be held to warrant us in publishing our own investigations, which have been more fortunate in their results than those of our eminent predecessors, and put the existence of the lymphatics of the bladder beyond all doubt. If, however, we have been more fortunate than our more eminent fellow-workers, our success is not to be ascribed to greater skill, patience, or perseverancé, but principally to the fact that we have hit upon better methods of investigation, supplemented by appliances introduced by ourselves, and under conditions that experience has enabled us to recognise. When we consider the character of the technical methods employed in the past for investigating the lymphatic system before the introduction of the use of solutions of silver, we can scarcely feel surprised at the small measure of success which has rewarded the labours of others in investigating the lymphatics of the bladder; for in that organ they are so very few in comparison with some other tissues, and so irregular, and even abnormal as compared with the distribution in other organs, that only by a rare accident could they ever have been demonstrated. As far as the present study of the comparative anatomy of these lymphatics in different animals is concerned, and the almost absolute necessity of examining them in their simplest form as found in the bladders of the smallest mammals, it would have been a physical impossibility to have done so by any of the methods of injection hitherto in use, as for example, in the bladder of a mouse, whose wall when distended

appears to be of the thickness of tissue paper, the whole organ when contracted forming a little pellet no larger than a mustard seed. Indeed, the present paper might very appropriately have been made the place for a review of the comparative merits of the various technical methods hitherto employed for the investigation of the lymphatic system, as there can be no doubt that the supposed absence of lymphatics in certain tissues and organs is an opinion due to the unsuitable character of such tissues and organs for the various methods of injection of the lymphatics within them, and of these the organ in question might be shown to be the most typical example. On the other hand, we must credit the injection methods with far greater errors in the opposite direction, through demonstrating vast lymphatic arrangements where they probably do not exist, as shown in certain well-known researches into the lymphatics of the liver, spleen, kidney, and similar organs. Such a review would, however, unduly lengthen the present paper; we shall therefore reserve it for another research to be published shortly, and at once proceed to the method with its special modifications and precautions, by means of which we have been enabled to demonstrate the course and relations of the lymphatics of the bladder, and which must be closely adhered to by others wishing to verify our results. Even supposing the lymphatics of the bladder to have been completely demonstrated by the injection method, it would still be a great gain to have demonstrated them by the silver method also, owing to the gross errors due to injection methods now existing in the anatomy of the lymphatic system, and leading to equally unfortunate conceptions as to its physiology and pathology.

In addition to the mere technical knowledge of the employment of silver solutions, the present investigation requires special manipulation and precautions to be taken according to the size of the animal. Under all circumstances, the animals selected should be as lean as possible, as fat, even if completely confined to the fat cells, gets shed in the necessary manipulations, and the tissues, thus rendered greasy and in a manner waterproof, do not allow of satisfactory imbibition and consequent differentiation by the silver solutions. The next condition to be obtained is one of primary necessity in the case of every

animal, both great and small; the wall of the bladder must be distended to its utmost capacity, for no method hitherto proposed is capable of demonstrating the lymphatics in question if the wall of the bladder be either flaccid or contracted. This distension has to be attained in various ways according to the size of the animal, and the surface of the bladder to be treated. In the case of the horse, as an example of a large bladder, we need not attempt to demonstrate upon it the great efferent lymphatics on its outer or peritoneal surface, as these are too large and extended for microscopical examination. Moreover, the bladder wall is too thick to be rendered transparent when the internal surface is to be treated with silver and examined by transmitted light, and the following steps are therefore necessary.

As soon as the animal is dead, the bladder is extracted with a portion of the urethra and ureters attached. The latter having been ligatured, a cannula with stopcock is inserted and tied into the former, and the bladder, having been emptied of urine, is well washed out with distilled water. Air is then pumped in with the ordinary injection syringe until the bladder is distended to its utmost capacity. It will now be found easy to dissect the whole of the musculature off the mucous portion of the bladder, and this portion is thin enough to be rendered transparent, and does not contract injuriously when the bladder is opened into and the distending air allowed to escape. Different parts of this inner portion of the bladder wall may now be excised and mounted on the histological rings invented by us,[1] the epithelial side lying upon the outer surface of the tambourine thus formed, whence the epithelium may be more or less completely removed by scraping it off with a scalpel. A 1 or 2 per cent. solution of nitrate of silver in distilled water is then quickly poured on and off one or both surfaces, and after exposure to a dull light for a few minutes, the whole is washed well with distilled water, and a 1 per cent. solution of chloride of gold in distilled water is applied for a minute to either or both of the surfaces which have been silvered. It is then well washed and carefully exposed, turning, if possible, the untouched surface to the light (when either surface exists

[1] See *Jour. de l'Anat.* for Jan. 1879, or *Journal of the Royal Microscopical Society* for June 1879, page 357.

as such), so that the metallic salt may be first reduced at its deepest zone of penetration into the tissues. In this condition it may be examined from time to time under the microscope, and if it prove to be a successful preparation, it may be clarified in the usual way with glycerine or oil of cloves, and the disc *afterwards* excised and mounted as a permanent preparation.

Under almost all circumstances it is inadvisable to inject the bloodvessels previously with transparent coloured injection. Apart from the fact that such coloured injection generally gets bleached by the action of the silver solution where it touches it, and that the injection tends to render the tissue less transparent, the injection is unnecessary; for the silver shows the bloodvessels distinctly wherever these exist in the neighbourhood of any lymphatics made apparent, the character of all the vessels being made evident by the cell-markings of their walls, and the relationship with the rest of the tissues being satisfactorily demonstrated.

As for the size of the histological rings employed, it will be found that those of an inch inside diameter[1] are most convenient, but those of two or even three inches diameter may sometimes be found advisable where it is desired to investigate the relation of lymphatics upon a large portion of surface, such for example, as the trigone, and it is always advisable to have a sufficient number of pairs of rings at hand to be able to utilise the whole of the bladder wall, as only a small percentage of preparations may prove successful. It is also to be borne in mind that when a portion of tissue has once been mounted on the rings, it must not again be removed from them until it is either to be definitely rejected as worthless, or has been finally clarified for permanent preservation as a preparation.

The same steps that we have enumerated in the case of the horse are applicable to the bladders of sheep, goats and swine, only in these cases great care must be taken not to distend the bladder unduly, as the lining epithelium becomes readily fissured, and the surface partially destroyed for examination. Where it is inadvisable or difficult to dissect off the musculature, the bladders after distension may be hung up for a few hours, so as to render the muscular wall less ready to contract when opened

[1] Rings of this size are supplied by Messrs Burge & Warren, 42 Kirby Street, Hatton Garden, London, E.C., at ten shillings per dozen pairs, prepaid.

into. The sensitiveness of the living tissues to the silver reagent does not seem to be appreciably affected by that lapse of time, according to our experience.

It will, of course, be understood that the preparations obtained by the foregoing method in large animals merely give the minute anatomy and relationships of small portions of the lymphatic supply, like the portions shown in figs. 2 and 3, from the sheep, as only such can be placed under the microscope. To get a view of the general plan of the lymphatic system as it is applied to the bladder as a whole, one must have recourse to the bladders of the very smallest mammals, where, as in fig. 1, the greater part of the lymphatic system may be seen almost within the same field of the microscope. Indeed, as the portion of bladder wall from which fig. 2 was drawn, was only $\frac{1}{3}$ of an inch square, and the lowest power of the microscope under which the lymphatics could be recognised and differentiated from the other vessels, gave a camera lucida drawing 8 inches square, from which fig. 2 was afterwards reduced by photography, the impossible size of a drawing of the lymphatics of the whole vesical wall in which these vessels were large enough to be recognised, may easily be imagined. It is for this reason that the comparative anatomy of the lymphatics of the organ in different sized animals becomes of special utility.

The foregoing method, applicable to the bladders of large animals, it is impossible to use in the case of the smallest mammals, for which, therefore, special manipulations are necessary. If not altogether impossible, one could rarely succeed in distending with air the delicate bladder of a mouse, which when distended is only of the size of a large pea, with walls of exceeding tenuity. Even if this could be done, and the muscular tissue would not subsequently contract, there would scarcely be sufficient extent of tissue to be distended, even upon a very small ring; and, moreover, owing to the amount of tissue wasted by this process, only a portion of the surface of the organ could thus be prepared at one time.

Under normal conditions, the bladder of a mouse is generally found more or less contracted or empty of urine; and if violence were used or fear occasioned in destroying the animal, the little urine contained within the bladder would certainly be shed, and

the organ contracted. Special precautions are, therefore, necessary, first, to obtain a bladder fully and naturally distended by urine, and secondly, to prevent the urine from being shed. If rats and mice in confinement are liberally supplied with water, they keep on drinking it and playing with it. Their bladders are then continually found distended with urine, and such examples, if carefully treated, serve well for demonstrating the lymphatics near the outer surface. The plan we follow is to kill the animal almost unconsciously with chloroform, then to throw a ligature round the neck of the bladder, so as to enable us to take the organ out of the body. The outer surface having been treated by the silver and gold solutions in the manner already described, and sodden in glycerine, which soon destroys all contractile power in the muscular wall, the small organ is placed on a glass slide and snipped in the necessary directions to convert the spherical wall into a plane surface, and it may afterwards be sealed up as a permanent preparation. In this way fig. 1 was prepared from the outer surface of the bladder of a mouse, distended with urine, and it shows perfectly the general plan of the main efferent lymphatic channels of the mammalian bladder.

Although, however, the extreme thinness of the musculature of the bladder in these little animals enables us to recognise the branches or affluents ramifying amongst the muscle fibres, it gives us none of that certain evidence of their relation to the mucous surface which only preparation of the tissue from that surface could afford, and we have not yet been able to devise a method by which a sufficient amount of tissue of the bladder of the mouse could be prepared to demonstrate the lymphatics upon the mucous surface. We have, however, succeeded in rats, and preparations thus obtained show that in these little creatures the lymphatics are arranged on the same principle as in the bladders of the larger mammals.

Finally, in treating of the bladders of animals of the size of the rabbit or Guinea pig, we have introduced modifications which may even be necessary in the case of contracted portions of the same organ from the larger animals. When in these animals we wish to demonstrate the lymphatics on the outer or peritoneal surface of the organ, it is advisable to distend them with air as previously recommended, and to treat that surface as recom-

mended in the case of the mouse. When, however, the inner surface has to be treated it is useless distending the organ, which may be at once divided into any two halves. We then take a slab of cork, such as is used for cork soles, into which a number of circular holes of different sizes have been cut, capable of letting the different sized rings pass tightly through them. Choosing a circular hole of apparently appropriate size for the tissue to be prepared, the portion of bladder is stretched evenly across it and fastened by small pins in the cork at the edge of the hole, the epithelial surface being left uppermost. It is now easy to apply the lower ring of the pair through the hole and jam the upper ring upon it, with the tissue stretched as a membrane between the two, which may then be prepared according to previous instructions.

When we study and compare the lymphatics of the bladder of the smaller with those of the larger mammals, we find that, notwithstanding the difference in size, there is a wonderful identity between them, both as regards their size, distribution, and relationships, an identity that is by no means common in other organs, and which is due probably to the similarity in shape which prevails in this organ in the different classes of the mammalia; whereas the great modification in the shape of such organs as the uterus, pancreas, intestinal canal, &c., causes considerable difference in the arrangement of their lymphatic system. The general plan of the lymphatics of the bladder taken as a whole throughout the mammalia, presents considerable divergence from the general plan of the distribution in other organs, a divergence which is due probably to difference both of structure and function; and in order to appreciate it thoroughly we must carefully keep in mind the structure of the bladder itself, and the manner in which that differs from organs formed of similar tissue.

Although, like the intestinal canal, the bladder is described as possessing or being formed of four coats, the mucous, submucous or areolar, the muscular and serous coats, coming in similar order in both, yet the plan of the lymphatics in both is essentially dissimilar. In the first place, probably in consequence of a difference of function, the great layer of submucous collecting lymphatics of the intestinal canal may be said (with one excep-

tion, to be afterwards noted) to be almost unrepresented in the bladder. Again, in the intestinal canal the lymphatics (or lacteals) may very distinctly be divided into two categories,—1st, the collecting or submucous, and 2d, the efferent, including under that head the so-called intermuscular and subserous lymphatics. In the bladder no such clear distinction exists, for the collecting and efferent lymphatics seem blended together at what may be considered their ultimate source, as if the function of collecting had, with certain exceptions near the orifice, by means of some slight modifications, been grafted upon the terminal valved lymphatics, as shown in figs. 2, 3, 4 and 7. In the greater part of the bladder, moreover, there is no abrupt termination of a lymphatic corresponding to the lymphatics of the villi, and the ultimate lymphatic vessels remain in the condition of endless loops or chains, for the most part accompanying the bloodvessels, an abnormal condition for ultimate or collecting lymphatics.

Again, in the intestinal canal we have the two distinct layers in the muscular coat, in each of which respectively the fibres lie in one definite direction, but at right angles the one to the other, and acting in correspondingly different directions at different times. These separate the submucous and subserous lymphatics into two very distinct layers (without taking into account a third, the intermuscular, which Auerbach has almost unnecessarily described as a special layer, for it is merely a portion of the plexus of efferent lymphatics), but no such arrangement exists in the bladder, no portion of whose lymphatics can well be described as a special layer. These comparative differences in the plan of the lymphatics in two organs formed of the same elements and arranged in the same order, are evidently due to modifications in the arrangements of each of these layers, and it is in the specific structure of each of them as they exist in the bladder, that we may expect to find the reason why they differ not only from the arrangements in the intestinal canal, but from the general plan of the lymphatics throughout the body.

In order to understand the plan of these lymphatics, we must form our conceptions of the structure of the organ especially in relation to that plan, and consequently differing from those generally taught. We may put aside entirely the layers of cells

which form respectively its serous or peritoneal and its mucous or vesical coats or layers as having practically little connection with its lymphatic system, and concentrate our attention upon the muscular coat, with its matrix of gelatinous or so called white fibrous tissue, which also forms a lining or layer on either of its surfaces, and contains, besides the muscular elements, the whole of the bloodvessels, lymphatics and nerves of the organ. For our present purpose, moreover, the musculature of the bladder cannot be conceived or described as formed into distinct layers, dissections notwithstanding. The bundles of smooth muscle fibres or cells, which form it lie upon and across each other at every variety of angle, and pass continually from one surface to the other, like the lymphatics amongst them, the only group of fibres worthy of special notice being the broad thin layer or band of parellel fibres lying upon the peritoneal surface of the musculature in the antero-posterior line of the body, extending for a certain distance on either side of the mesial line, and shown at *lm.*, fig. 1. It is evident that there is a special relationship between that band of fibres and the main chain of efferent lymphatics on either side of the mesial line before they leave the organ, the course of the lymphatics being parallel to the direction of the fibres, whose general formation has probably led to the band being adopted near its outer borders as the track most suitable for the main lymphatic vessels.

In our use and conception of the term gelatinous tissue or matrix, we wish it to be understood that, as far as the natural condition exists, or the action of the silver and gold reagents used by us is concerned, no such term as fibrous or areolar can be applied to it. It is a structureless hyaline matrix, staining dark purple by the reagents employed, and showing all cell-formed tissues within it as bright white objects. This explanation may assist in making our preparations and drawings more intelligible.

Let us now follow the course of the lymphatics in their relation to the structure of the bladder as we have described it. Laying aside altogether the text-book dictum that "the lymphatics of the bladder enter the glands near the internal iliac artery," as insufficient and incorrect, let us trace the main lymphatic channels backwards from the points where they leave the bladder. These points are mainly two, one being the neck of

the bladder and the other the urachus, as shown in fig. 1, where the two great efferent lymphatic streams are seen in the relation they bear to each other, and to the great band of superficial muscle fibres upon or at the border of which they are placed. Each of the two groups was drawn separately by the camera lucida, and afterwards joined so as to lie in the straight line which they naturally form, but which had been made artificially into a curve by the conversion during the preparation of the spherical wall into a plane surface; and as they are there presented, they give a true picture of the plan of the lymphatics which encircle the bladder for a certain distance on either side of the mesial line of the organ. Beginning at the upper border of the drawing, we find the embouchure of the group of efferent lymphatics, which leave the bladder at the upper or anterior surface of the neck of the organ, and whose affluents are drawn from the whole of the anterior or inferior surface of the one side intervening between the neck and the urachus *u*, the most distant superficial affluents taking their drainage material from the tissues at the base of the urachus, forming an anastomosis there with the embouchure of the great efferent lymphatic or lymphatics which leave the bladder by way of the urachus. From that point the lymphatic stream first mentioned passes downwards and backwards on the anterior surface of the bladder, gathering in affluents as it goes, forming two great channels in the present case, but in other specimens it may have either one or more large trunks which pass towards the neck and leave the organ at that point. The other great group having its embouchure at the urachus, midway down the drawing, was probably the main one in fœtal life. Passing from its embouchure, we find the lymphatic stream flowing from the fundus and back of the bladder, gathering in its affluents from every side, and from the neighbourhood of the neck of the bladder posteriorly, and pouring the lymph thus collected through one or more main streams which leave the bladder at the urachus.

In addition to these two great streams on each side of the bladder, we have numerous smaller branches passing from the sides of the bladder towards the neck, but these are of little extent and importance as compared with the two great streams

figured in our drawing. It ought, however, to be stated that it is very seldom that so complete a demonstration can be obtained as that shown in fig. 1. This is probably due to the fact that the main efferent lymphatics do not always lie so superficially, and that only portions of the line of vessels are generally made evident.

Although near to their embouchure, those lymphatics lie almost entirely within the layer or coating of gelatinous tissue on the peritoneal surface of the musculature, they cannot be spoken of as a separate system of subserous lymphatics. Under all circumstances, there is a certain thickness of gelatinous tissue interposed between them and the serous cells of the peritoneum, and even close to their embouchure thin isolated bundles of muscular tissue may be seen at various places to intervene between the main lymphatic and the serous endothelium. Moreover, it is to be observed that all the affluents which form the main stream by their junction proceed from the substance of the musculature, and nowhere do they commence in the organ as the superficial subserous plexus seen elsewhere in the body. When we track these numerous affluents backwards from their junction with the main stream, we find them passing obliquely through the felting of muscular bundles until they reach the inner surface. This can be specially well seen in the bladder of the mouse, where the musculature is so extremely thin that, when treated from the peritoneal surface, the lymphatics may be traced to a great extent throughout their course. In many instances, after reaching the inner surface, they may be observed to turn again backwards, and become superficial for a short distance on the peritoneal surface of the musculature, showing thus the effect of the irregular or felted character of the musculature in destroying all resemblance to the sheets or layers of lymphatics seen in the intestinal canal, and which are evidently due to the regular arrangement of the muscular layers.

To observe the intimate relations of these lymphatic affluents with the inner or mucous surface of the musculature, it is generally advisable to use preparations treated from that surface, and for that purpose we must select the bladders of the larger mammals, which are large enough to be mounted and prepared on histological rings. While describing that surface, let it be

understood that the lymphatics have special relations to it at the trigone which they do not possess elsewhere upon the great extent of inner surface of bladder wall exclusive of the trigone. We will, therefore, for the moment, leave the surface of the trigone out of consideration, and speak only of the great mass of bladder wall as a whole. The general relationship of the lymphatics to the inner surface is shown in figs. 2, 3, and 7 from the bladders of the sheep and mare, which were drawn from preparations treated from the peritoneal surface, after the greater part of the musculature on that surface had been removed, for the purpose of allowing the reagents to penetrate as far as the vesical epithelium; and in fig. 6, from the monkey, which had been treated from the inner surface. It must, however, be understood that the lymphatics do not appear everywhere on the wall as plentifully as they are seen to do in those drawings, the spots from which they were drawn having been specially selected for that purpose, on account of the greater number of the lymphatics seen there, and the more intimate relations which they consequently showed with the bloodvessels and other tissues of the same locality.

A peculiar feature to be noticed here is that the lymphatics seem to be found as a rule only in the neighbourhood of the lines of the bloodvessels, around which they twine and alongside of which they lie in a close relationship that is seldom found in other organs or tissues. These parallel groups of bloodvessels and lymphatics are not found as a rule upon the outer surface, but only upon the vesical surface of the musculature or within its felted bundles, and do not lie, as elsewhere, wholly within the internal or mucous layer of gelatine. Indeed, bloodvessels, lymphatics, and muscle bundles seem to form a feltwork with each other specially characterised by its irregularity. It often happens, moreover, that a lymphatic is seen to emerge suddenly from the mucous surface of the musculature and to pass into the gelatinous layer, where it makes a short knee-like bend, and passes again as abruptly back into the musculature, these irregularities being similar to those we have described as taking place very frequently beneath the serous surface of the organ.

This peculiar relationship between the lines of bloodvessels and intertwining lymphatics, on the one hand, and the absence of

any special system of valveless collecting lymphatics, as seen in other tissues, on the other hand, suggest a limited function for the lymphatics of the bladder, a function confined to taking up at once the lymph or serum exuded from those great bloodvessels, and thus preventing it from passing into the bladder through the sodden epithelial cells which line it, while at the same time there are no collecting lymphatics close to that surface for the purpose of acting as the draining adjuncts to that area as in the case of the submucous lymphatics of the intestinal canal, lest from their position they might also drain off material from the cavity of the bladder injurious to the organism. Although immediately underneath the epithelial lining of the bladder there is a very thin layer or network of blood capillaries, yet that layer is almost too insignificant in normal conditions to cause an exudation of lymph or serum into the bladder, or to require an arrangement on its deep surface to carry away the minute quantity of lymph exuded from the plexus. This condition may explain, on the one hand, why there appears to be little or no perceptible absorption from the vesical cavity in normal conditions, but great absorption in inflamed conditions, where absorption would be probably due to and confined to the distended bloodvessels, and not to the lymphatics at all, and, on the other hand, why in cases of cystitis the amount of albumen to be found in the urine seems to be excessively great in proportion to the amount of pus contained in it.

It appears also probable to us that the lymphatics of the bladder represent a condition which, if it cannot exactly be called a rudimentary type, might at least be called an instance of arrested development. We have found that in embryonic life, as a rule, the lymphatics are represented to a great extent only by those vessels which afterwards become the special efferent lymphatics of tissues and organs, and that, as growth progresses, we have a continuous development from the peripheral extremities of these existing lymphatics of the special collecting and generally valveless lymphatics. This continuous development in the lymphatics does not even cease when the adult state has been attained, but becomes more plentiful as age advances, as may be well seen in studying the collecting reservoirs on the lower surface of the diaphragmatic musculature in

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young and old adult animals of the same species. We are of opinion, therefore, that the lymphatics have developed in the bladder only to the stage of efferent vessels in the neighbourhood of the smaller arteries and veins. Having reached that point, instead of developing a system of collecting lymphatics without valves away from the neighbourhood of the bloodvessels, they have merely modified their condition by forming rudimentary meshes or loops intertwining with and around the bloodvessels, sufficient to carry away the lymph exuding from these vessels, but unfitted to act the part of a general drainage system for the whole surface.

Again, if the commonly used term of subserous lymphatics be ever applied to the efferent lymphatics seen in fig. 1, it must be understood as applied only relatively, and in no such sense as it is often applied elsewhere to collecting lymphatics,—like those, for example, found on the lower surface of the musculature of the diaphragm. The branches which form these efferent lymphatics are seen without exception to emerge from the musculature, and never to commence either as loops or as terminal branches within the substance of the subserous layer of gelatine. Indeed, they bear a similar relation to the serous surface that the roots of trees bear to the surface of the ground.

When we turn to the mucous surface, we find that here the lymphatics have just as little claim to be described as arising from or as forming a submucous category, for the collecting lymphatics we have described seldom appear so far from the substance or surface of the musculature as to be wholly embedded in the gelatinous layer of that surface. We may therefore reject as an entirely erroneous guess the dictum of Cruveilhier, that the lymphatics of the bladder arise from both surfaces; and similarly we may dismiss the even more indefinite guess of the former compilers of Quain's *Anatomy*, who describe the lymphatics as arising from the whole surface of the organ, without specifying which surface they refer to, or if both surfaces are included under the head of the whole.

With regard to other conditions, we may note that, notwithstanding the large size of the vessels, and the large number of crenated endothelial cells in the circumference of the walls of the larger lymphatics of the bladder in large mammals, as seen

in fig. 3, from the sheep, these walls receive no strengthening elements in the shape of muscle, or branched cells, or fibres while they remain within the substance of the organ, even in so large an animal as the horse.

This, however, is merely a feature they possess in common with the lymphatics of other organs in all the mammalia we have yet examined. In such cases, the strengthening muscular coat or coats of lymphatic vessels only appear in the great efferent trunks extrinsic to special organs. Notwithstanding that, in figs. 2, 3, and 6, the three companion structures—arteries, veins, and lymphatics—appear to be of somewhat similar dimensions, it must be borne in mind that, while arteries and veins diminish in size, and can be traced in the preparations to their ultimate capillary twigs, the lymphatics, on the other hand, seldom become much smaller than they appear in these figures, although they are to be found very much larger. As shown there, the lymphatics may be held as representing the ultimate radicles of the lymphatics in what is by far the greater portion of the wall of the bladder. Indeed, the general rule throughout the body is that, unlike the bloodvessels, the lymphatics constituting the ultimate radicles of the system are very much larger than the efferent lymphatics continuous with them, and to which they bear the same relation that a lake or reservoir bears to its efferent stream. This is very evident in the collecting lymphatics of the lower surface of the musculature of the diaphragm, in the lymphatics of the mucosa of the whole intestinal canal and many other localities, and this principle is even represented in the bladder in the case of the lymphatics of the mucosa of the trigone, which we previously pointedly excepted from the foregoing description of the lymphatics of the rest of the bladder-wall. To the lymphatics of that exceptional portion of the mucosa we now proceed.

It is unnecessary for us to enter here upon a description of the difference between the general mucosa of the bladder and that firm, smooth portion overlying the trigone, which accounts for the peculiar character of the lymphatics found within it. Figs. 4 and 5 from the mucosa of the trigone of the bladder of a monkey, sufficiently explain the character of these lymphatics, fig. 5 being drawn to the same scale as figs. 2, 6, and

7 for comparison with them. It is easy at once to recognise that those large irregular lymphatics forming *culs de sac* are undoubtedly the collecting and commencing vessels of that system, and that they are in continuation with the deeper-lying ordinary lymphatics on the surface of the musculature, similar to those shown in fig. 6 from the side of the orifice of the bladder in the same animal. These lymphatics in figs. 4 and 5 bear no relation whatever to the bloodvessels of the locality, and lie, as a rule, immediately underneath the superficial network of blood capillaries which extends over the whole of the inner surface of the organ.

The mucosa here is much thicker than elsewhere in the bladder-wall, the gelatinous matrix being filled with branched cells which have no connection with the lymphatics, and with smooth muscle cells or fibres which lie either as irregular small bundles or as solitary cells unconnected with the general musculature of the wall, and at times lying even superficial to some of the lymphatics. In short, those irregular shaped dilated lymphatics being merely projections from the ordinary lymphatics of the wall formerly described which form numerous anastomoses with each other, may strictly be considered as the actual commencement of the lymphatics of the bladder. Indeed, apart from the isolated group shown in figs. 4 and 5, taken from the centre of the trigone, the ordinary lymphatics show a tendency to throw off dilated branches whenever they approach the neighbourhood of the trigone, as seen in *e*, fig. 6, which locality is on the left of the anterior angle T of the trigone. It ought scarcely to be necessary for us to repeat here what we have so often repeated elsewhere, that there is no evidence whatever that more minute lymphatic radicles exist in the shape of minute canals formed by the cells of the connective tissue or the cavities in which such cells lie. Although in certain structures, as, for example, the subserous layer of the parietal peritoneum, the branched cells are so numerous that they often appear to be in connection with the lymphatic channels found there, yet elsewhere, and the bladder is a tissue or organ in point, these branched cells are seldom seen near lymphatics, except when, as at *c*, fig. 3, they are due to the presence of blood capillaries, from which capillaries they have probably escaped as wandering cells,

the numerous branched cells within the mucosa covering the trigone being exceptional in character like those of the peritoneum, but even then they have no connection with the lymphatics. It may, however, be necessary for us to go on repeating such statements until certain German investigators cease drawing hypothetical branched cells in formal connection with lymphatic channels, and teaching that these cells, or the cavities in which they lie, are the radicles of the lymphatic system. It would be too much for us to deny that future investigators may yet demonstrate lymphatic radicles of which at present we can form no conception. What we affirm is, that as the silver and gold solutions show all cell-formed or protoplasma-lined canals in our preparations as bright white elements in the purple hyaline matrix of gelatine, no lymphatic radicles like those described could exist without being made evident. Hitherto they have certainly not been made evident; they have only existed as hypotheses, not as facts, at all events in the mammalia.

Another hypothesis, equally unfounded, and due to the same school of investigators, may demand a passing word in connection with that portion of the bladder which is covered by the peritoneum. Although we have already shown that the lymphatics of the bladder, even where they exist in the subperitoneal layer of gelatine, have their affluents all coming from the musculature, it might still be suggested that they had a connection with the peritoneal cavity by means of the stomata which certain German observers have described in serous cavities, and more especially upon the lower surface of the centrum tendineum of the diaphragm. If such orifices did exist, we might fairly expect to find them even more readily at the bottom than at the top of the cavity, as fluids are generally held to seek the lowest and not the highest level, and if they exist on the diaphragm they ought also to exist upon the bladder. We have examined, in numerous instances, the silver-marked peritoneal endothelium covering the bladder as well as several hundred specimens of the diaphragm, and have invariably failed to find any evidence of the existence of such structures as stomata. Laying aside, however, our own observations in the matter, although as the discoverers of the great collecting lymphatic

reservoirs on that same surface of the diaphragm, where our predecessors, quick to observe minute objects, failed to observe these large objects, we might fairly claim to have examined that surface even more carefully than they had done; laying aside also the complete reversal of the simplest principles of hydrostatics, which absorption of fluids through stomata on the roof of the peritoneal cavity entails, we can still offer one anatomical objection to the hypothesis that the peritoneum forms part of the lymphatic system which it will be difficult to overcome. That objection lies in the character of the crenated endothelium found throughout the lymphatic system, never wanting there, never found elsewhere, and never found lining the peritoneal cavity of the mammalia. The cells lining that cavity resemble much more the endothelium of veins than of lymphatics. No similarity, however, exists between the structure of the peritoneum and that of the lymphatics, so that even hypothetically there is no foundation for establishing an anatomical connection between the two by means of stomata or other imaginary communication. As for the physiological experiments of Professor von Recklinghausen, who first started the hypothesis, we have only to remark that, even if the almost unavoidable injury done to the delicate walls of the reservoirs we discovered on the same surface of the diaphragm did not fully account for absorption from that surface of milk and Berlin blue, so as to fill the whole lymphatic system of the structure, the fact that, to effect absorption, the natural position of the structure of the animal had to be reversed, must vitiate the deduction he derived from the experiment. Apart, however, from the hypotheses, if stomata existed at all in the peritoneum, they ought to have existed on the peritoneal surface or covering of the bladder in connection with its subserous efferent lymphatics. This they certainly do not, and, speaking plainly, we hold the existence of stomata in the mammalia to be either imaginary or the result of rough manipulation.

Before concluding this paper on the lymphatics of the bladder, it may be well to give a short résumé of the results obtained from the physiological and clinical experiments on the absorbing cavity of the urinary tract, in order that our readers may form their own conclusions as to the relationship between the

anatomical and physiological conditions. For most of the facts of this abstract, we are indebted to an exhaustive account published in 1871 by Dr Alling,[1] that being the latest work on the subject that we have been able to discover. Dr Alling begins his subject by stating that, at that date, even in spite of the numerous works that had been published during the past fifty years, the most contradictory opinions were still upheld by physiologists and medical men, who could not be brought to accept any one general conclusion on the subject. First, M. Sejalos (père) in 1824, admits the absorption of medicinal substances by the bladder. M. Sejalos (fils), in 1862, thinks he can agree in the foregoing opinion, and regards absorption there as being at least as active as in the stomach. Bérard also admits it, but to a less extent than by other mucous surfaces. Civiale considers absorption to be nearly absent. Professor Longet came to the conclusion that absorption took place, but he admitted that his observations might not always appear conclusive to every one. MM. Susini and Kuss, in 1867, absolutely deny that any absorption takes place; M. Dumarquay admits it to a certain extent. M. Bert, in 1869, at the Société de Biologie, announced that, as the result of experiments, he had proved absorption by the bladder to take place; and, at the same time, M. Brown-Séquard remarked that in Russia and Italy advantage was taken of that fact in the treatment of cholera. In 1867, Sir Henry Thompson denies absorption by the bladder; while Dr Braxton Hicks asserts the contrary.

Alling's own results were as follows:—

1st. The healthy bladder does not absorb appreciably either medicinal or poisonous substances.

2nd. The healthy urethra absorbs both.

3rd. Absorption very readily takes place in the inflamed bladder.

He also explains the contradictory views by stating that, with the exception of Susini, all those who had found absorption had tied the urethra at the meatus, and they had consequently mistaken absorption by the urethra for vesical absorption. He had opened the abdomen in dogs, tied the neck of the bladder,

[1] *De l'Absorption de la muqueuse vésico-uréthrale*, par le Dr Edouard Alling, Paris, 1871.

and tested with atropine and strychnine. He also tested with morphia upon his own bladder and found absorption *nil*, he being at all times very sensitive to the drug. Dr Braxton Hicks' observations were in agreement with his own experiments, that observer having injected morphia into the empty bladder in cystitis, where the concurrent inflammation accounted for the great absorption.

Finally, to sum up the results of our own observations upon the lymphatics of the bladder, we formulate the following conclusions:—

1. Strictly speaking, the only pure collecting lymphatics of the bladder are to be found (with slight and immaterial exceptions) in the mucosa covering the trigone. These may therefore technically be considered the origins of the lymphatics of the bladder.

2. Generally speaking, the lymphatics of the bladder do not arise from either surface, but exist in their ultimate form as a mixture of collecting and efferent lymphatics, forming irregular elongated loops or chains accompanying and intertwining with the lines of smaller arteries and veins, which form great meshes upon the inner surface of the musculature of the organ.

3. From these endless loops, larger branches, generally unaccompanied by bloodvessels, pass very obliquely through the substance of the musculature. These affluent branches anastomose frequently with each other, and upon the outer surface of the musculature form by their junction the larger or main efferent lymphatics.

4. These efferent lymphatic vessels are well provided with valves, and lie principally within the gelatinous layer or matrix intervening between the serous endothelium and the musculature, and thus pass on either side of the mesial line, some towards the urachus and others towards the neck of the bladder, at which points they leave the organ and have no further connection with it.

DESCRIPTION OF PLATE XXXI.

Drawings made by the aid of the Camera Lucida.

Fig. 1. View of the main efferent lymphatics in the bladder of a mouse. These lie for the most part at and parallel to the border of the superficial longitudinal band of muscle *lm* on either side of the mesial line of the organ. *u*, urachus, towards which a main efferent lymphatic *el*, passes round the fundus from the base near to the line of *ah*, the inferior hypogastric artery. On either side of the anterior border of the base of the urachus, another great lymphatic stream collects its affluents *al*, and passes downwards towards the neck of the bladder near *ag*. The affluent lymphatics *al*, are generally seen coursing within the muscular wall for some distance before joining the efferent streams *el*. $\frac{1}{15}$.

Fig. 2. View under a very low power of the collecting lymphatics on the mucous side of the muscular wall of the bladder of a sheep at the fundus, showing their peculiar general relationship to the blood-vessels of the part. *a*, arteries; *v*, veins; *l*, lymphatics; *m*, muscles; *n*, nerve bundle. $\frac{1}{4}$.

Fig. 3. Magnified view of a portion of the lymphatics seen in fig. 2, at its upper border, showing the intimate relation of the lymphatics *l*, with the bloodvessels and other tissues. This figure was drawn from the untouched mucous surface, while fig. 2 was drawn from the opposite surface of the preparation. *a*, artery; *v*, vein; *m*, muscles. A number of branched cells, probably wandering cells, are seen near the capillaries at *c*. $\frac{1}{80}$.

Fig. 4. Terminal collecting lymphatics or reservoirs lying within the mucosa of the trigone of the bladder of a monkey, immediately underneath the superficial capillary plexus of bloodvessels. *m*, smooth muscle fibres, solitary and in small bundles; *v*, veins; *b*, branched cells in matrix of gelatine surrounding the lymphatics. $\frac{1}{80}$.

Fig. 5. View under very low powers of the cluster of lymphatics from a portion of which fig. 4 was drawn. It is drawn under the same power as figs. 2, 6, and 7, for comparison with these as to size. $\frac{1}{4}$.

Fig. 6. General arrangement of lymphatics on the inner side of the musculature of the bladder of the monkey, on the left side of the orifice of the urethra. *O*, orifice; *T*, left anterior angle of the trigone; *l*, lymphatics; *v*, veins; *e*, dilated lymphatics corresponding to collecting vessels: Where the lymphatics seem abruptly to end, they are merely passing into the musculature. $\frac{1}{4}$.

Fig. 7. Peculiar sacculated condition of lymphatics of the inner side of the musculature of the bladder of a horse, near its orifice, for comparison as to size and distribution with those of the monkey and the sheep in figs. 2, 5, and 6, being drawn under the same power. *av*, arteries and veins; *l*, lymphatics. $\frac{1}{4}$.

NOTES ON A DISSECTION OF A CASE OF EPISPADIAS.

By R. J. ANDERSON, M.D., *Demonstrator of Anatomy, Queen's College, Belfast.*

THE pelvis had been divided on each side of the middle line in front of the acetabula. The anterior wall of the abdominal wall is complete. The depth of the symphysis or its representative is half an inch, the distance between the pubic bones half an inch, the space between being filled with fibrous tissue. The bones are very movable at the joint. Below the pubes the skin passes into mucous membrane at the front and sides, and a funnel-shaped opening leads into the bladder. This opening is situated below the pubes at a distance of three quarters of an inch from the upper border of the fibrous band. Below the orifice is situated the penis, three inches in length, flat and grooved on the upper surface. The groove extends the whole length of the organ, and becomes somewhat wider near the anterior extremity. Near the anterior extremity two lateral grooves or fissures are situated, each three quarters an inch in length. Foramina are to be seen on the floors, and by drawing the penis forwards the openings of the ducts of Morgagni and the verumontanum come into view. The penis is terminated by a glans, bordered by a prepuce with a frænum; the former is confined to the lower surface, and is at the frænum one inch in length; but it diminishes towards the sides. On running the finger and thumb along the penis, the corpora cavernosa can be felt as two separate bodies, but more distinctly behind than in front. At a distance of three quarters of an inch behind the anterior extremity of the penis, they become more closely united, and immediately in front of this a slight change in the resisting power of the tissue is felt. The scrotum is large, and the testes can be felt on each side; these bodies are small (age of subject, 84). The perinæum is perfect behind the scrotum.

The bladder is of moderate size and the walls of normal thickness. An opening above and behind shows the mucous membrane to be slightly tinted red. The ureters have the usual position, their ducts open one and a half inch behind the pubes. The verumontanum is best seen by drawing the

posterior wall of the bladder back; it forms a considerable elevation, which is greatly increased by injecting water into the vas deferens of either side. The openings of the ducts are situated near the upper border of the elevation, and close to one another. The vasa deferentia are somewhat increased in size as they descend on the posterior wall of the bladder; each is joined by the vesicula of its own side. The latter receptables are somewhat smaller than usual. The prostate is large, and bounds the neck of the bladder behind and slightly at the sides. It is firm on pressure.

The erectores penis and ejaculatores urinæ are present; the latter present a somewhat flattened appearance. Their attachments do not deviate materially from the usual condition. The crura are fixed behind in the normal position, and pass forwards and inwards, and widen slightly behind the glans on passing air into each crus; it does not pass into the glans nor from one side into the other.

The corpus spongiosum, smaller than usual, is situated in the middle line between the crura, and diminishes in size anteriorly; less than half an inch wide behind, it is less than a quarter of an inch at the junction of the crura, and is continued forwards between these bodies.

The triangular ligament is well formed and firm. The subpubic opening will admit the index finger on pressure, but it is not patent.

Dissections of epispadias with and without ectopia vesicæ have been previously made, and accounts of these and other cases have been recorded.[1]

The abnormality may be accounted for by referring the condition to an arrest of development or failure of lateral parts to meet in the middle line, or by supposing rupture to take place at an early period. That failure of the lateral parts to meet in the middle line cannot sufficiently account for the presence of the ectopia vesicæ, which so frequently occurs with epispadias, Professor Cleland has shown, unless indeed the view of Reichert and Remak[2] be adopted, that the allantois is

[1] Professors Humphry, Turner, and Cleland, *Journ. of Anatomy*, vols. iii and v.

[2] Foster and Balfour, *Embryology*, p. 148.

developed by two processes, which subsequently afterwards coalesce. And if this view be adopted, it will be necessary to assume their incomplete coalescence.[1] Vrolik[2] considers the presence of ectopia vesicæ with a partial epispadias, as in Baillie's case, where the posterior part of the urethra was bridged over, an argument against the hypothesis of rupture. That, however, urine must appear in the abdominal cavity in case of rupture, does not necessarily follow if close apposition of the urinary tube with the abdominal wall have previously taken place. The fringed borders were absent in the above noted case and others. The corpus spongiosum, it will be seen, has a position between the crura and the corpora cavernosa. The body was narrow, yet the breadth of the flattened penis was increased. The corpus spongiosum was inflated for some distance (2–3 inches) from the bulb. Three facts especially deserve attention. The position of the prostate, which is almost confined to the posterior (inferior) part of the bladder; secondly, the high position of the urethral orifice; and thirdly, the condition of the urethral groove. All these point to a transference of the urinary orifice forwards. A displacement backwards of the tube from the upper level of the prostate to the anterior extremity of the groove, without alteration in the position of the corpora cavernosa, would reduce the parts to the normal position, provided that the corpus spongiosum be moved back also for some distance. Hence, in the above case, without reference to ectopia vesicæ, there is evidence of a dislocation forwards of the urinary passage from the prostate (posterior border) to the extremity of the urethra. If, then, at a period when the crura have not yet united, the septum between the intestine and the urino-genital tube be completed, and the orifice of the latter be placed farther forwards than usual, unless indeed a corresponding change take place in the position of the crura, the latter will come to occupy the posterior part of the orifice, the corpus spongiosum may have its free development interfered with, and the urethra will be incompletely covered. The urethral opening, taking the average of 22 cases, male and female, was situated 2½ inches below the upper border of the symphysis; in

[1] See Budge, "Ueber die Harnblase bei Vogelembryonen."—*Deutschen Med. Wochensch*, No. 8, 1881.

[2] Frolik, *Cyclop. of Anat. and Physiology.*

the case of epispadias, the distance was three quarters of an inch.

The condition of the ectopia vesicæ may be referred to the same cause. If the opening of the primitive urinary tube be placed very much farther forwards than usual, namely, in a part where active increase in the tissues takes place, a foramen which would remain relatively small if maintained in the ordinary position, may become large by participating in the growth of the tissues, or by representing an amount of tissue absent. And the increase of the bladder which gives this viscus its character would be very different when compared with an opening placed higher up than the usual position.

Baillie's and Luschka's cases may be explained by the fact, that the corpus spongiosum is more free behind.

THE MORPHOLOGY OF THE MUSCLES OF THE TONGUE AND PHARYNX. By R. J. Anderson, M.D., *Demonstrator of Anatomy, Queen's College, Belfast.*

Accounts have been given of the muscles of the tongue with a view to determine their position and relations (morphologically) to the surrounding parts. These have generally been regarded by anatomists as useful in acquiring a knowledge of the muscles rather than exhaustive inquiries into their exact relations.

The tongue seems to be a special appendage of the pharynx, for although it is first to be recognised in the chick as an elevation in the floor of the mouth, it receives only its mucous covering from the epiderm. The tongue is placed in relation with the first, second, and third arches at its earliest appearance, and in front (or below) the primitive digestive tube, a position which it maintains in the adult. The development of the air tube also limits the area of formation, and its connection with the visceral arches formed in connection with the pharynx, as well as the relations of the parts in the adult, point to a similarity existing between the muscles of the pharynx and those of the tongue.

The muscles uniting the derivatives of the visceral arches with the base of the skull may be stated as follows:—Muscles uniting the base of the skull with the first arch,—the internal and external pterygoids (in part), the tensor palati, and laxator tympani; the base of the skull with the second—the stapedius (formed in connection with second); first with second—an occasional bundle of stylohyoid; first with third—the anterior belly of the digastric geniohyoid and geniogloss; the second and third—stylohyoid, and occasional slip of stylopharyngeus; third with the base of the skull—posterior belly of the digastric. The latter serves to unite the base of the skull in some animals with the first as is well known, and occasional slips in man have been seen. The septal muscle, situated between the genioglossus of opposite sides, may be regarded as a hyomaxillary or accessory genioglossus.

The connections of the pharynx and tongue with the base of the skull are as follows:—The pharynx is connected to the base of the skull by a true cephalo-pharyngeus (occasionally present), the levator palati and a portion of the tensor palati by means of the palato-pharyngeus; to the first arch by means of the superior constrictor; to the second and third arches by means of the middle constrictor and stylopharyngeus. The tongue is connected with the base of the skull by the tensor palati through the palato-glossus to the first arch by means of the styloglossus (occasional slip) and genioglossus; to the second by means of the styloglossus and chondroglossus; to the third by means of the keratoglossus and basioglossus. The inferior lingualis may be placed in the last-mentioned set. The septal muscle already referred to, which is single (Henle), or double (Luschka), and which is rarely absent according to Bochdalek, may be considered an additional hyoglossal muscle developed in the fibrous tissue of the septum.[1]

The varieties of the tongue and pharyngeal muscles present many points of interest in this connection. A styloglossal slip (and sometimes the whole styloglossus muscle) arises from the inferior maxilla; an example of the former occurred in a subject dissected during the present session. The maxillary slip was half-an-inch broad at its origin, and partially connected with the internal pterygoid; the organ was tendinous. An accessory stylohyoid muscle was present on both sides of the body, the stylohyoid ligament being also present, which had connections similar to the muscle. A slip has been seen passing to the pharynx (Sandifort).[2] In a female subject, aged seventy, on the left side a slip from the posterior border of the styloglossus passed over the stylohyoid ligament, and was continued into the fibres of the middle constrictor. Professor Gruber has seen a slip from the external auditory meatus to the tongue. A slip from the corpus triticeum has been seen to pass to the tongue separately or in connection with the keratoglossus.[3] In one case, in which the lingual artery passed over the keratoglossal fibres, a stylohyoid muscle replaced the ligament of the same name, gave a

[1] Henle's *Eingeweidelehre*, p. 106.
[2] Macalister, *Trans. Roy. Irish Academy*, vol. xxv.
[3] *Op. cit.*, p. 108.

slip to the posterior thyrohyoid ligament, and a thin band to be inserted into the great cornu of the os hyoides; on the opposite side of the body the muscle replaced the ligament also. In this case the middle constrictor fibres, destined for the lesser cornu of the hyoid bone, passed over the lingual artery and beneath some fibres of the hyoglossus. The palato-glossal fibres are continued into the transverse fibres of the tongue.

The Pharyngeal Muscles.—The superior constrictor has been seen to give fibres to the mylohyoid at its attachment to the inferior maxilla and to the buccinator at its buccal attachment. The lower fibres have been seen to pass into the genioglossus and hyoglossus. They are stated by Professor Henle to pass into the transverse fibres[1] in front of the palato-glossal fibres. The results of several dissections lead me to believe that they are continuous, at least in great part, with the genioglossal fibres. The middle constrictor receives sometimes a slip from the base of the skull. This variety occurred during the present session. The slip was attached above to the vaginal process of the temporal bone, external to the attachment of the levator palate, and part with the middle constrictor, in part separately reached the middle line posteriorly. This muscle and also the middle constrictor have been seen to receive slips from the thyrohyoid. In a case already referred to, the middle constrictor received a bundle from the posterior border of the styloglossus, and sent a bundle with the styloglossus to the tongue. The stylo-pharyngeus has been seen to give off a bundle to the stylo-glossus, and to be inserted into the uvula, epiglottis and thyroid cartilage.

The normal connections of the muscles of the tongue and pharynx, taken with the variations sometimes met with, point to an intimate relation existing between those of the former and those of the latter. The continuity of the pharyngeo-glossal fibres with those of the transverse lingual and genioglossal fibres seem to show that the latter are developed from the differentiated inner layer of the digestive tube, and in the same set may be placed the palato-glossus. The normal attachments of the middle constrictor to the hyoid bone and its styloid connection, together with its occasional attachment by a slip to the inferior

[1] Macalister, *op. cit.*

maxilla, seem to show that this muscle may be considered as derived from the same pharyngeal differentiated mesoblast layer, as the styloglossus and hyoglossus and inferior lingualis. The interchange of fibres, and their variation of attachment, point in the same direction.

The superficial lingual muscle is probably developed from the covering of epiderm, and is comparable with the subcutaneous muscles of other regions.

The nervous supply of the parts bears out generally the homology. The muscles are supplied in one case by the hypoglossal, in the other by the spinal accessory through the vagus. These nerves may be both regarded as spinal nerves, or as parts of a fourth cranial nerve, of which the glosso-pharyngeal and vagus represent the anterior divisions.[1] The mucous membrane of the tongue is in great part supplied by the fifth, as it is derived from a region supplied by that nerve. The nervous supply of muscles above the level of the distribution of the first mentioned nerves receive the facial or fifth in accordance for the most part with the early distribution of these nerves to the second and first arches. These nerves may be considered as representing a third cranial nerve, of which the greater part of the third represents the sensory part. The fact that the styloglossus receives a branch, sometimes from the digastric branch of the facial, is interesting, when the supply of the other styloid muscles is taken account of.

The vertical lingual fibres, which are not included in the above account, are considered by many as detached portions of the genioglossi, whilst others deny their existence as separate fibres.

The muscles of the tongue have been examined by Meckel[2] in the various animal classes, and the following represents the general condition as given by him :—

In Proteus of the amphibia there are three pairs of muscles on each side of the tongue bone. Of these the anterior passes from the posterior extremity of the second lateral cornu to the anterior of the first and the anterior of the mesial bone. The

[1] Gegenbaur's *Anatomy*, p. 700, *et seq.* Krause, *Allgemeine und microscopische Anatomie*, p. 403. Krause, *Anatomische Varietäten*.

[2] *Anatomie*, B. iv.

middle, close to the median line, extends from the anterior and inner end of the second cornu to the mesial bone. The third from the posterior end of the third cornu to the middle of the second cornu.

In Rana and Bufo a longitudinal, perfectly or imperfectly divided muscle, extends from the posterior cornu of the hyoid bone to the anterior end and the whole circumference of the tongue, which it draws back powerfully. Even though in some the tongue cannot be protruded, the muscles are present.

The muscles acting on the hyoid are as follows :—

The depressor connected more or less with the rectus abdominis. In the tailed batrachia it is this muscle which passes from the inner surface of the clavicle to the posterior extremity of the hyoid bone.

The retractor or omohyoid is attached to the inner surface of the middle or mesial piece of the scapula and the hyoid bone.

The elevator passes from the styloid bone to the upper and posterior part of the second lateral cornu.

The hyomaxillary from the inferior maxilla to the mesial piece of the hyoid or the beginning of the posterior cornu.

A muscle passing from the inferior maxilla of one side to that of the opposite side is also present.

In ophidia, the protractor arises from the anterior extremity of the inferior maxilla, and may be traced to the middle of its whole length.

The retractor arises from the posterior extremity of the tongue bone, and forms almost the whole of the tongue substance.

Near the middle line a special hyomaxillary muscle is present, which goes from the inferior maxilla anteriorly to the posterior extremity of the body of the hyoid. Posteriorly, this muscle passes into another, which is attached to the most anterior ribs and the trunk muscles as far as the spines of the dorsal vertebræ, where it meets its fellow of the opposite side in the median line.

In *Python bevittatus*, the retractor of the hyoid has an oponeurotic origin, from the spines of the cervical vertebræ, lying close beneath the skin; it is broader at its origin than at its middle part, and passing obliquely behind and below the inferior maxillary articulation, it converges towards the muscle of

the opposite side, and is inserted into the anterior extremity of the tongue bone.

The protractor comes from the cartilaginous connection of the inferior maxillæ, and mixes behind with the hyoglossal muscle; it is inserted into the internal inferior and external surfaces of the hyoid (cornu), and it surrounds the hyoglossus like a sheath.

Between the anterior thirds of the cornua a triangular muscle, with the apex turned forwards, is present; it is thin and membraneous; a decussation of the fibres has not been observed.

A muscle comparable with the mylohyoid is present in *Python b.*, which is united posteriorly with the cervico-maxillary muscle. It arises from the inner surface of the inferior maxillæ, and is inserted into the outer part of the hyoid bone. The subcutaneous muscle joins it behind; at first a decussation of the fibres takes place, and then they become continuous. Meckel and Hubner regarded this muscle as the platysma; and the former anatomist gave it the name subcutaneous muscle of the neck.

A muscle is found beneath the posterior depressor of the lower jaw; but farther back, and upon which the retractor of the os quadratum lies, may be regarded as a muscle of the hyoid bone. Its fibres mix with those of the preceding muscle anteriorly, of which it is the antagonist. It may be named the cervico-hyoid.

A muscle arises with the geniohyoid (protractor), separates from that muscle, and is inserted into the air tube, which it draws forward.

A muscle that draws back the larynx arises at the attachment of the geniohyoid and hyoglossus to the bone, close to and above the former, outside the latter, and is inserted into the thyroid cartilage.

The lingualis arises from the hyoid bone posteriorly, and passing forwards joins its fellow of the opposite side in the median line at an acute angle, and by the anterior separation of these muscles the bifid tongue is produced.[1]

In Chelonia, the retractor of the tongue extends from the inner end of the anterior cornu of the os hyoides to the lateral border of the tongue.

A second is found in Chelone, more posterior and external,

[1] D'Alton, in *Müller's Archiv*, 1834.

which passes from the anterior two-thirds of the anterior cornu to the lateral border of the body.

A third in Chelone beneath the first passes from the small mesial sublingual cartilage into the tongue substance.

The protractor is larger than the latter, but smaller than the other tongue muscles.

The depressor of the hyoid bone arises from the outer end of the clavicle, and goes to the cornua of the hyoid bone. An omohyoid is wanting. The elevator arises from the posterior extremity of the inferior maxilla, and passes from before and without backwards and inwards to the outer end of the anterior cornu. A hyomaxillary muscle is present, and corresponds in its attachment to the whole length of the maxilla, and descends far into the neck.

The protractor is strong, and passes from the place of union of the inferior maxillæ to the inner half the anterior cornu.

In Crocodilia, the retractor of the tongue arises from the middle of the bony cornu, and passes into the posterior half of the tongue by six or seven processes.

In Crocodilia, the protractor is double. The parts arise from the anterior extremity of the lower jaw, the outer and larger passing along the outer border of the tongue to its posterior extremity. The inner, much smaller, unites towards the posterior part of the tongue with that of the other side, and reaches into the middle round the hinder border.

In crocodiles and other reptilia, the depressor of the hyoid bone passes from the sternum to the hyoid, and sends a process to the inferior maxilla.

The retractor or omohyoid arises from the scapula, and is inserted into the middle of the bony cornu.[1]

The elevator moves the bone to the side, and extends from the muscles attached to the inferior maxilla (inner surface), and is inserted by two processes into the lateral border of the hyoid plate, and behind to the outer half of the lateral cornu. The intermaxillary muscle passes from one side to the other without interruption. The deep hyomaxillary muscle arises from the middle of the inferior maxilla near the upper border, and is inserted into the middle of the lateral cornu.

[1] Episterno-hyoideus, Episterno cleido-hyoideus of Saurians.

In birds, the lingualis is attached to the posterior part of the tongue (glossohyal), and is inserted into the anterior part. Fleshy behind, it terminates in a long tendon which passes along the under surface of the tongue close to the median line. The hyoglossus arises from the side of the anterior piece of the mesial part of the hyoid (basihyal), and is inserted near the base of the tongue at the outer part of the upper surface. The ceratoglossus arises from the long posterior cornua surrounded at its orgin by the geniohyoid, and terminating in a long tendon, is inserted into the lower surface of the tongue external to the lingualis. The ceratohyoid (ceratoural) arises from the cornu near the anterior part, and meets its fellow of the opposite side in the median line, or is inserted into the posterior piece of the mesial portion of the hyoid. The former condition obtains in the goose, duck, and common fowl, the latter in the parrot. The muscles of the hyoid are the so-called stylohyoid, which arises from the posterior part of the external surface of the inferior maxilla near the lower border, and divides into two pieces, one of which is inserted into the median raphé beneath the urohyal, or into this bone; and the anterior slip passes beneath the ceratoglossus to be inserted into the basihyal beneath the hyoglossus. The geniohyoid arises from the inner surface of the inferior maxilla, and surrounds the posterior cornua at its insertion, forming a sheath for the ceratoglossus. In some birds a muscular band attached with the preceding to the inferior maxilla passes to the median raphé beneath the urohyal. A basithyroid muscle extends from the thyroid cartilage to the basihyal, where it is attached above the hyoglossus. A thin membraneous intermaxillary muscle extends from the lower jaw of one side to that of the other. It is divided into two parts by a median septum. In the parrot, in front of the anterior portion of the geniohyoid, a slip united with the latter at its origin passes inwards to meet its fellow of the opposite side in a median septum, forming thus a groove over which the hyoid apparatus moves. In the same bird a genioglossal slip, arising from the inferior maxilla near the anterior part, is inserted with the hyoglossus into the tongue.

The lingualis of birds is similar in position and connection to the muscle sometimes (always Bochdalek) present in man at

the side of the median line internal to the geniohyoglossus. The hyoglossus of birds occupies nearly the position of the basioglossus of mammalia, very much enlarged and extended in these latter. The muscle named stylohyoid by Professor Owen differs from that attachment of the muscle of the same name, not only at its origin, but at its insertion. The portion inserted into the basioglossus, having regard to the alteration, corresponds more nearly to the styloglossus, or probably to the styloglossus and stylopharyngeus combined; whilst the posterior part represents the stylohyoid, or rather that portion, not present in all birds, which is attached to the posterior mesial part of the hyoid bone. The muscle in birds occupies a position in front of the same named muscle in man. If a displacement (relatively) of the muscle backwards take place with the development of the proximal parts of the second arch, so that the expansion would not only reach the second arch, but pass over the walls of the digestive tube to reach or extend beyond the middle line behind, meeting (or decussating) with the muscle of the opposite side, then a condition approaching that of mammalia would be obtained, a greater relative growth in the breadth of the base of the skull separating the styloid process from the subjacent structures would render the condition identical with that of mammalia as far as one portion of the pharnyx is concerned. The extension of the muscular fibres along the cornua of the hyoid bone and the thyroid cartilage would produce the middle constrictor and stylopharyngeus respectively. The pharyngeal fibrous coat would then correspond to the muscular layer of the digestive tube of birds. If with a movement downwards and backwards of the larynx (upper) a shortening of the hyoid cornua (posterior) take place, an extension backwards of the genioglossal fibres, which are already in immediate relation with the digestive tube, will produce that portion of the superior constrictor called mylopharyngeus, whilst a growth forwards will produce the geniohyoid and genioglossus in man. In the parrot, a special band on each side represents the latter, and in the same bird I have found the geniohyoid proper consisting of two bands on each side. The ceratoglossus of birds, by a similar extension, would produce that portion of the superior constrictor known as glossopharyngeus.

Examples of muscular extensions to fit certain structures for definite actions are not wanting in the animal series. In that of python, given above, a retractor of the os hyoides extends back to the vertebral spines; and a muscle, having a similar action in the os quadratum, reaches the nuchal fascia. The examination of the omohyoid in man and animals show that this muscle may be reduced to a muscular slip, or have an extensive attachment to the scapula and clavicle.

It is of interest to note in this connection that the depressors of the hyoid bone are known to extend (in part) into the tongue as a permanent (sloth) condition, and examples are known where the sternothyroid was continued into the tongue and middle constrictor muscles.

ON THE SO-CALLED MOVEMENTS OF PRONATION AND SUPINATION IN THE HIND-LIMB OF CERTAIN MARSUPIALS.

By ALFRED H. YOUNG, M.B., F.R.C.S., *late Assistant Lecturer on Anatomy, The Owens College, Manchester.*

AMONG the higher vertebrates, the articulations between the tibia and fibula are rarely of such a nature as to permit of even modified movements of pronation and supination. There are, however, certain marsupials—the Koala (*Phascolarctos cinereus*), the Wombat (*Phascolomys*), the Phalangers (*Phalangistidæ*), and the Opossums (*Didelphidæ*)—in whom the bones of the leg so articulate with each other, that movements are permitted which, so far as the results are concerned, may fairly be compared to those of pronation and supination occurring at the radio-ulnar articulations in the forearm of many vertebrates. But whatever similarity there may be in respect of results, the mechanism of the movements themselves is very different in the fore and hind limbs respectively. It is to this difference that I now wish to draw attention. In so doing, it seems advisable, in the first place, to briefly indicate such anatomical points as are essential for the consideration of the matter. These for the most part are derived from dissections of the hind-limb of the Koala, and to this animal the following descriptive notes more particularly allude. I have assured myself, however, that the corresponding structures both in the Wombat and the Opossum are practically identical.

In the Koala the superior extremity of the fibula so articulates, by means of an elongated (antero-postero) sightly concave articular surface situated upon its inner side, with the convex outer surface of the external tuberosity of the tibia, as to be capable of moving, with comparative freedom, both forwards and backwards. Both tibial and fibular surfaces are coated with articular cartilage, and the two bones are held loosely together by lax ligamentous fibres, which are attached to the margins of the articular surfaces. The movements of the fibula are chiefly limited by the strong external lateral ligament of the knee joint, which is attached to the head of the bone. Inferiorly the

tibia and fibula are held together by loose ligamentous fibres, but are prevented from direct articulation with each other by the intervention of a bony prolongation from a partially ossified fibro-cartilage, which intervenes between the lower end of the fibula and the astragalus.

A strong and well-defined muscular mass occupies the whole length of the interval between the tibia and fibula; it is situated behind a thin interosseous membrane, from which it is inseparable. The fibres of the muscle pass obliquely downwards and inwards from the fibula to the tibia; to the fibula they are attached along the entire length of its internal (anterior) border; whilst to the tibia they are attached to the internal border and posterior surface of the bone in its upper part and below this to the external border and external surface, the lowest fibres reaching indeed as far as the anterior border of the shaft of the tibia. In the Koala the muscular mass is single and undivided, and in that animal may be regarded as comprising the *popliteus*, together with the *pronator tibiæ* of Humphry.[1]

In the Opossum there is an indication of its subdivision into two such components.

Now, with respect to the movements of pronation and supination in the hind-limbs of the animals above referred to, it is clear that, so far as the bones of the leg are concerned, they are entirely due to movements of the fibula upon the tibia. Professor Mivart[2] points out that "the tibia never assumes that crossed position in relation to the fibula which the radius assumes in relation to the ulna, and which is termed pronation. Nevertheless," he adds, "a modified action may take place in certain marsupials, viz., the Phalangers and Wombat." Professor Huxley[3] states that "in the Wombat (*Phascolomys*), the Phalangers (*Phalangistidæ*), and the Opossums (*Didelphidæ*), the fibula is capable of a rotatory movement upon the tibia, similar to the movement of pronation and supination of the radius upon the ulna in man." Sir Edward Home, in his account of the movement of pronation in the hind-limb of the Wombat,[4] affirms that "the fibula is

[1] *Observations on Myology*, p. 27.
[2] *Lessons in Elementary Anatomy*, p. 202.
[3] *Anatomy of Vertebrate Animals*, 1871, p. 279.
[4] *Phil. Trans. Roy. Soc., Lond.*, 1808, p. 304.

pulled entirely forwards, and that it possesses a slight rotatory movement inferiorly."

But a careful consideration of the form and character of the surfaces which enter into the formation of the tibio-fibular articulations in any of these marsupials will show that it is not to a rotatory movement of the fibula that the movements of pronation and supination of the foot are to be attributed; that under the most favourable circumstances, indeed, any such rotatory movement must necessarily be extremely limited.

It has been already pointed out that the tibio-fibular articulations admit of movements in the antero-posterior directions only; these movements are simply those of gliding and coaptation.

Referring to the muscular arrangements in connection with these joints, it is important and interesting to note the precise relationship of the muscular attachments in different regions of the limb, with special reference to the action of the corresponding fibres. Superiorly the internal border of the fibula runs forwards and becomes anterior, so that in this region the fibular attachment of the muscle under consideration is situated on a plane considerably in front of the tibial; contraction of the muscular fibres will tend to bring both attachments to the same plane and to approximate them, a result which is obtained by a *backward* and inward movement of the upper extremity of the fibula. Conversely, the inferior fibular attachment is on a plane posterior to that of the tibial; contraction of the muscular fibres of this region results in approximation of both attachments to the same plane and to each other; and again it is effected by a movement of the fibula, but in this case the movement of the lower end of the bone is *forwards* and inwards. The total result of the action of the *pronator tibiæ* is that the fibula is thrown obliquely across the tibia, and these bones are approximated. This constitutes the so-called movement of pronation. There is no absolute rotation such as occurs in the movement of pronation in the forearm of man; the tibia throughout remains stationary, whilst the tendency to internal rotation of the superior extremity of the fibula is counterbalanced by a tendency to rotation in the opposite direction of the inferior extremity.

A CONTRIBUTION TO THE PATHOLOGICAL ANATOMY OF PNEUMONOKONIOSIS (*Chalicosis pulmonum.*) By THOMAS HARRIS, *Student in Medicine at the Owens College.* (PLATE XXII.)

(*From the Pathological Laboratory of the Owens College.*)

IT is a well-established fact that persons engaged in certain occupations, in which they are exposed to the inhalation of various irritant solid particles of dust, are particularly liable to some pulmonary affections, which both in their clinical features and in their pathological products differ from the ordinary forms of phthisis. To these affections the generic term of Pneumonokoniosis, first introduced by Zenker (*Deutsch. Arch. f. Klinische Med.*, vol. ii., 1867) is now universally given; and according to the nature and character of the irritant, certain forms are distinguished, the chief of which are anthracosis, chalicosis or silicosis, and siderosis; anthracosis being due to the inhalation of carbonaceous particles to which miners and others are subject; silicosis being due to the inhalation of siliceous matter—stone-masons, potters, pearl-shell cutters, &c., exhibiting this variety most frequently; and siderosis being due to the irritation caused by particles of red oxide of iron being inhaled. (Unfortunately Quincke [*Deutsch. Arch. f. Klin. Med.*, xxvii., 1880] has recently applied this term siderosis to a general pathological condition, characterised by an excess of iron in the system, and its deposition in certain organs of the body). Besides these, other forms, due to the inhalations of dust containing metallic or vegetable particles, have been described affecting the workmen engaged in the respective manufactories; but while the existence of some of them, such as tabacosis, is as yet doubted by many; other forms, such as byssinosis (or the disease produced by the inhalation of cotton fibre) do not differ from the ordinary forms of phthisis.

It is not my intention to review the general pathological anatomy of these different forms, especially as this has been done most satisfactorily by Hirt (*Krankheiten der Arbeiter*, 1st part, 1871), Charcot (*Revue Mensuelle*, vol. ii., 1818) and quite recently by Balzer (*Dictionnaire de Méd. et de Chir.*, vol. xxix.,

article "Pneumonokoniosis"), and by Proust (*Dict. de Méd. et de Chir.*, article "Maladies professionnelles"), not to mention a very large number of papers on this subject, detailing cases or giving the results of experimental studies. I merely wish to draw attention to some interesting points in the histology of silicosis, which have not been hitherto described.

Silicosis pulmonum is chemically characterised by the presence of a large amount of silica in the lungs (Meinel, Greenhow, &c.) and anatomically by the presence of numerous small hard nodules. Clinically, it runs usually a slow course, which has, somewhat artificially, been divided into three stages, the first marked by cough (with expectoration of sputum containing silica) and dyspnœa; the second by loss of flesh, slight hæmoptysis and the physical signs of patches of pneumonia; while in the third, the symptoms are those of phthisis, with night sweats, hæmoptysis and the physical signs of lung cavities. The cases which have hitherto been reported are, as far as I can learn, all cases where the disease ran this course, and where the *post-mortem* examination showed, besides the characteristic nodules, a number of other changes. The case which is the subject of this communication may be considered as an example of the early stage of the disease, and was uncomplicated by any other lesion, for while, during life, the chief symptoms were cough and dyspnœa, the latter to such an extent that the case was thought to be one of mechanical obstruction to the air passages, and the physical signs those of bronchitis, the lungs after death were found studded over by thousands of little nodules, and beyond slight consolidation of both apices by a firm, fibrous, black mass, showed no other changes, such as softening or cavitation.

The patient, a stone-mason, aged 37, was admitted into the Manchester Infirmary, under the care of Dr Simpson, on Feb. 4, 1880, and died a week after admission from excessive dyspnœa. The physical signs during life were chiefly those of bronchitis. The *post-mortem* examination was made by Dr Bradshaw, then pathologist to the Infirmary. The following extract from the *post-mortem* record describes the condition of the lungs. (The other organs showed no noteworthy change. The heart was neither dilated nor hypertrophied.) The right pleura was found adherent over the upper lobe, and considerably thickened over the apex. The

left pleura was generally adherent. The lungs were bulky, did not collapse, and were thickly studded on their surface with elevated hard black nodules, about the size of swan shot. The apices were firm and unyielding. On section the nodules projected from the surface of section, and were seen to be *thickly* scattered throughout the substance of both lungs. The size was usually that of a split pea, some being smaller, but none larger; in colour they varied from steel grey to black, and cut with a firm section. They were more numerous near the surface than near the roots, and in the upper than in the lower lobes; they were on a crimson-red ground of lung substance. The lungs as a whole floated in water, and the lung substance between the nodules was for the most part crepitant. No aperture was seen in any of the nodules, and no caseous changes were found in any part of the lung. The apices were consolidated, being converted into greyish black solid masses. Bronchial glands were considerably enlarged, indurated, and somewhat pigmented.

The point to which I wish specially to call attention is the existence of these numerous distinct small hard blackish nodules which *thickly* studded a lung tissue, itself for the most part crepitant.

Observers seem far from agreed as to the exact nature and mode of development of these bodies. Rokitansky looks upon them as miliary tubercles, to which in their appearance and distribution throughout the lungs they bear a certain resemblance. Rindfleisch regards the nodules as taking origin from the lymphatics.

Meinel, in a thesis published in 1869, analysed nineteen cases of pulmonary disease, all occurring in stone-masons, which had been observed at the Pathological Institutes of Dresden and Erlangen between the years 1854 and 1869. Eight of these cases were characterised by the presence of small black nodules varying from the size of a millet seed to that of a pea, scattered all through the lungs, most numerously in the upper parts, where they formed confluent masses. Chemical analysis of these lungs showed an increased quantity of silica. He showed that they were not tuberculous but fibrous, and in the centre he often found a small hyaline body in connection with the nodules, which he attributed to a particle of silica. In some of his

cases, apart from these nodules, he found also tubercles. The same author, in 1876 (*Vierteljahrs f. Hygiene*), refers to the experimental rasearches of Dr Von Ins on the inhalation of particles of silica, believes from these that the particles from the alveoli enter the lymphatics, and that the whole process runs its course chiefly in the lymphatics, and that the little nodules are due to an accumulation of cells containing particles of silica and of fibroid material resulting from the irritation set up.

Dr Peacock, in a paper on French millstone-makers' phthisis (*British and Foreign Medico-Chirurgical Review*, 1860, vol. xxv. p. 214), gives the notes of two cases where in the lungs of two millstone-makers small cavities existed, and the lungs were studded with what are described as grey miliary tubercles. In one of the cases tubercles are described as existing in the lungs in masses, with the interposed pulmonary tissue comparatively sound; yet in the record of the microscopical examination of the diseased portions, nothing is said about tubercles, it being stated that "the diseased masses appear to be made up of dense closely arranged fibroid tissue, studded here and there with numerous irregular groups of black pigment, and generally with an abundance of granules and globules of various sizes." Whether these cases belong to the class I am considering, or were really tuberculous, does not seem quite clear.

Dr Greenhow has also described several cases where the lungs of colliers, pearl shell cutters, stone-masons, and potters contained small black nodules of various sizes, the lungs also showing much more extensive change. In the case of a collier reported by him, in the *Transactions of the Pathological Society* (London, 1869), the apex of the left lung was solidified, very dense, and pigmented. The rest of the lung was spongy, but everywhere deeply pigmented, and contained numerous firm black nodules, from the size of a hemp seed to that of a horse bean. Many nodules resembled india-rubber in consistence, and cut with a dry smooth section. In the centre of most the orifice of a small bronchial tube could be seen. Many of the tubes in the centre of the nodules were filled with yellow cheesy matter. The lower lobe also showed several small circumscribed deposits of pigment which stood out from the surface on section. The apex of the

right lung was consolidated, and showed circumscribed black deposits similar to those in the left lung, and also several opaque, yellow cheesy deposits about the size of peas, surrounded by indurated black lung. The microscope showed the bronchial tubes closely surrounded by masses of black pigment. At one point a transverse section of a bronchial tube showed the inner wall of the tube quite free from pigment, but immediately outside the wall there was a dense deposit of black pigment which appeared to surround the tube completely.

The same observer, in the *Transactions* of the same Society (vol. xxi. p. 66), describes dense, hard, well-defined nodules, varying in size from that of a hazel nut to that of a millet seed, as existing in the lungs of a pearl shell cutter. In the *Transactions of the Pathological Society* (vol. xvii.), Dr Greenhow reports a case of stoneworker's pulmonary disease, where a great portion of both lungs was consolidated, and scattered through the crepitant parts of the organs were a few small solid nodules, varying in size from a split pea to a small bean, which were on section pale in colour, but firm in consistence: these nodules, on microscopical examination, had the character of chronic inflammatory exudations, consisting of nucleated cells, nuclei, granular matter, and cells containing oil globules, interspersed with a little fibrous material and black pigment. In the same volume of the *Transactions of the Pathological Society*, Dr Greenhow describes a potter's lung, where in solidified tissue surrounding a rugged cavity was an aggregation of hard, perfectly black nodules, varying from the size of a hemp seed downwards. In all these cases the lung contained an excessive amount of silica. In several of the cases cavities of larger or smaller size were found in the lungs.

On microscopical examination of the lung, the appearance of which to the unaided eye I have already given, the nodules were seen to vary in shape, being oval, round, or of more irregular outline. They were distinctly fibrous and pigmented. Fig. 1, for which and its accompanying drawing I am indebted to the kindness of Mr A. H. Young, pathologist to the Manchester Royal Infirmary, shows such a nodule. The central and peripheral part of the nodule was pigmented, while usually there existed an intermediate part, which was either free or contained but little deposit. The pigment was collected around several centres,

usually around three or more, a central principal deposit and several peripheral minor ones. In some cases the pigment of the central deposit was arranged peculiarly, not as a spherical mass, but in a sinuous tract (fig. 1.) The pigment was dark, black and granular, and was apparently composed of carbonaceous particles; the granules frequently formed a network, at other times they were more irregular in their disposition. At certain points the pigment formed minute circles, at other places it was deposited in lines, as though channels had originally existed here, which had been the seat of pigmentary deposit. This sinuous arrangement of the pigment, with circular and linear deposits, suggested the idea that this central part was of comparatively recent formation, and that bloodvessels or some other channels had existed there.

The fibrous tissue of the nodules was arranged in a more or less concentric manner, except at the central part, where it was arranged in a direction similar to that of the pigment. The small peripheral deposits of pigment had their own concentric arrangement of fibrous tissue, but some of the deposits were also enclosed by the fibrous tissue of the principal part of nodule. The pigment of these minor deposits was more granular, and did not run together into a network, as did that of the central deposit. Sometimes in the centre of these smaller pigment collections, what was apparently a minute hyaline body could be detected, which occasionally had in its centre a point of black pigment; on examination with an objective of high power, this hyaline appearance was seen to be due not to any foreign body, as a particle of silica, but to a concentric and closely arranged fibrous tissue, in the centre of which was the point of black pigment. Some of the nodules also showed a general yellowish brown pigmentation. The peripheral part of the nodule was also pigmented as already described. This pigment was in the form of dark black granules, situated in embryonic tissue, and had apparently been more recently deposited than the pigment in the central part of the nodule. In this peripheral part an artery was occasionally seen showing typical endarteritis obliterans. With the exception of a few bloodvessels at the periphery of the nodules, the lumen of no channel was to be seen.

The lung substance surrounding the nodules was in a very hyperæmic condition, and this was more marked in the immediate neighbourhood of the nodules than at points more remote, and in many cases small hæmorrhages existed at the outside of a nodule. The alveoli around contained epithelial cells similar to those seen in catarrhal pneumonia, and a quantity of red blood corpuscles. The alveolar walls were somewhat thickened, and in some parts granular pigment was found in them. The lung substance round some of the nodules was in a state of atelectasis.

I then examined different sections to ascertain the exact mode of development of the nodules, and the parts which the several component parts of the lung played in the process.

In many places where the lung substance, except for the hyperæmia, was healthy, small bronchi were seen, on the outside of which black pigment granules were deposited. This deposit sometimes surrounded the whole bronchus, at other times it was limited to one side of the tube; but in either case the wall of the bronchus appeared intact, there being as it were a peri-bronchitis, in the new tissue forming which the pigment was deposited. The lumen of these small bronchi was in many cases quite free, at other times it was more or less encroached upon, apparently by pressure from without. In some parts the lumen of a certain bronchus was encroached upon by a new growth which arose from the innermost part of its wall. The nuclei of this growth were arranged in a stratified manner, and took the log-wood staining very well (fig. 2). The tissue arising from this *endo-bronchitis*, as it may be termed, was sometimes the seat of pigment deposit, at other times not. Some sections showed the peri-bronchitis and the endo-bronchitis progressing *pari passu*, the new tissue arising from both processes being at times seen to be deeply pigmented, the pigment being in the form of dark black granules, contained chiefly in round or oval cells. In some parts, intervening between the tissue that arose from the outermost part of the wall and that from its inner aspect, was a distinct zone of fully formed fibrous tissue, the original wall of the bronchus.

The bloodvessels in many parts showed similar changes to the bronchi; the adventitia being enormously increased, this in

some cases being not pigmented, or, as was more commonly the case, very much so. Further, a distinct new growth was in many cases seen internal to the elastic coat of an artery, the nuclei of which were stained markedly with logwood; this endarteritis was in some parts very evident, and encroached considerably on the lumen of the vessel.

As regards the lymphatics, these could not be distinguished with certainty from the other channels in the lung substance, but I believe a change also took place in them similar to that described in the bronchi and bloodvessels; since no part showed the change above described, while the surrounding channels were healthy; but where one tube was affected, there were in its neighbourhood several others showing a similar change. Further, the appearance and structure of the nodules, when fully formed, support this view, for there the development of fibrous tissue and the deposit of pigment had not taken place from a single centre, but from several centres, usually three or four. The peripheral cells of the cartilage of some of the medium-sized bronchial tubes were in a state of active proliferation; and it was in the immediate neighbourhood of bronchi of this calibre that the lung substance was in a state of atelectasis, and though the lumen of these medium-sized bronchi was perfectly free, the smaller bronchi and other channels immediately surrounding them were more or less obliterated, and the tissue around them deeply pigmented, the pigment being of apparently recent deposition, certainly more recent than that found in the nodules previously described. In this pigmented tissue numerous small channels existed, with very delicate walls, the lumen of many of which contained red blood corpucles, and in nearly all nuclei, which were stained readily with logwood, were seen bordering and encroaching upon the lumen of the tube; the pigment appeared to be especially collected around these vessels. It was in the tissue immediately surrounding these medium-sized bronchi, that the peri- and endo-bronchitis and the similar change in the bloodvessels was best to be studied. Sections examined from the apices of the lungs showed these parts to be in a state of complete fibroid induration, the remains of the alveolar walls being seen as wavy sinuous outlines. In this fibrous tissue were numerous

deposits of pigment, and in many places this was deposited in small nodular collections which were very similar to the nodules existing in other parts of the lungs, except that here they were surrounded by consolidated lung substance.

In no part of the lungs were any tubercles or caseous deposits found.

Through a great part of the lung being mislaid, I was unable to make any chemical analysis; but from the microscopical appearance, it may be stated with certainty that the chief part of the pigment was carbonaceous and not siliceous. Thus it seems that in this case, at least, the formation of the nodules did not arise from bronchial, arterial, or lymphatic changes alone, but that all these are to be taken into account; that probably the disease began as a peri-bronchitis in the new tissue, as a result of which the pigment was deposited; that this occurred principally around the capillaries and probably also the lymphatics in this tissue; and that subsequently an endo-bronchitis was set up, in which the same pigmentation occurred. That in addition a similar change occurred in the arteries, and possibly also the lymphatics of the lung. That these nodules when once formed increased in size at their periphery, and that eventually the intervening lung substance would have become consolidated exactly in the same way as it already had at the apices of the lungs, which were in a state of complete fibroid induration, in the substance of which the remains of the original nodules could be recognised. As regards the nature of the pigment in this case, I believe it to be in great part carbonaceous matter, while the diffuse yellowish brown colour of some of the nodules is to be attributed to changes in the blood-colouring matter consequent upon previous hæmorrhages, which were seen and described as existing at the periphery of the nodules. The man was a stone-mason, and hence some surprise might be felt at the pigment being chiefly carbonaceous; the explanation, however, which is given by Dr Greenhow of similar cases seems very probable, namely, that "fine particles of carbon find their way much more readily and more abundantly into the lungs of persons already suffering from chronic pulmonary disease."

It will thus be seen, that besides the accepted view that these nodules are formed by the entrance of particles of dust into the

lung alveoli, and their subsequent gradual passage into the lymphatics of the lungs,—a view which is chiefly based on the result of inhalation experiments (Kraus, O. Inns, Charcot, Proust, and others) and which is no doubt correct and sufficient to explain the peri-bronchitic changes, we have in this and in similar cases another and more direct mode of production, namely, by the formation of an endo-bronchitic mass, deposited outside the epithelial layer, and consisting at first of an embryonic tissue, which becomes then vascularised, and is eventually changed into fully formed fibrous tissue, and so completely obliterates the smaller bronchi. This condition of things readily explains the excessive dyspnœa which existed in this case, and which is so constantly found in similar cases.

In conclusion, I wish to acknowledge the valuable and kind assistance I have received from Dr Dreschfeld, both in looking up the literature of the subject and in the microscopical examination of the lungs.

ON THE HISTO [illegible]ME OF THE RARER FORMS OF MALIGNANT BONE TUMOURS. By ROBERT MAGUIRE, M.R.C.S.

(From the Pathological Laboratory of the Owens College.)

BONES are often the seat of primary malignant growths, which, clinically considered, resemble each other in many particulars; while, pathologically, they present very different types of structure. In spite of numerous investigations, we have as yet no uniform classification for these tumours, and even their clinical relations are far from satisfactorily established; thus, while Billroth believes that the histological structure does not allow any deduction as to the recurrence of the growth or the formation of secondary deposits in other organs, Gross makes the microscopical structure of the growth an important item in the prognosis of the case.

As regards the classification of these tumours, we find the greatest confusion amongst writers previous to the researches of Virchow (*Geschwulstlehre,* vol. ii. p. 289), and we find them described under such names as spina ventosa, osteo-cephaloma, osteo-aneurism, myeloid tumours, osteo-steatomata, cancer of bone, &c. Virchow, however, distinguished two large groups—the Sarcomata and the Cancers of bone. Since the researches of Thiersch and Waldeyer, most pathologists have denied the existence of primary cancer in bone, and have considered all forms of primary malignant bone tumours to be different varieties of sarcomata. Still, undoubted cases of primary cancer, both in bone and in other organs which develop from the mesoblast, have been described since the researches mentioned, and one tumour, which I have examined, and hope to describe in a subsequent paper, belongs to this type.

The *Sarcomata* of bone Virchow again divided, according to their origin, into the periosteal and central or myelogenic sarcomata. Of these, the first spring from the periosteum, are, as a rule, hard and firm, and have often entering into their composition a good deal of bony substance, when they are

called osteo-sarcomata;[1] while the central or so-called myeloid sarcomata are soft as a rule, have usually no bone entering into their composition, and often contain a large number of giant cells. Seeing, however, that, *firstly*, there are several forms of sarcomata according to the nature of the composing cell elements (myeloid, round and spindle celled, and alveolar sarcomata); and *secondly*, that the sarcomatous elements are often found to undergo development or degeneration, Virchow described a number of varieties, such as the fibro-sarcoma, chondro-sarcoma, osteo-sarcoma, and myxo-sarcoma, which may occur in both the periosteal and the central classes.

Other important features in some of these tumours are the preponderance and the condition of the bloodvessels; these being more or less of an embryonic type, may undergo such changes as to give rise to the presence of large spaces filled with blood, so that the tumour seems to be entirely composed of them; and from the fact that it has been found to pulsate during life, it has often been called aneurism of bone, a variety which is mentioned below under the term angeio-sarcoma.

Virchow's classification is adopted in most text-books of pathology, with the exception of that of Cornil and Ranvier, who do not give a separate classification for the bone sarcomata, but apply to them the same divisions as to sarcomata of other parts; thus, they recognise encephaloid or round-celled, fasciculated or spindle-celled, and myeloid sarcomata, and also a "sarcome ossifiant."

One of the most recent writers on this subject, Dr Gross ("Sarcoma of Long Bones," *American Journ. of Med. Science*, 1879), has essayed a more detailed classification. He divides the sarcomata into the periosteal and myelogenic varieties, making, in the former, the subdivisions of round-celled, fusiform-celled, and osteoid species; and in the latter, round, fusiform, and giant-celled tumours. The giant-celled variety Dr Gross has never met with in periosteal tumours of long bones. It is,

[1] It is well again to draw attention to the fact disregarded by many writers, that osteo-sarcoma and sarcoma of bone are not identical terms; sarcoma of bone being the general term applied to any primary sarcoma occurring in bone, whilst osteo-sarcoma, or better osteoid-sarcoma, applies merely to that variety in which bony matter is found in sarcomatous tumours.

however, often found in the form of epulis; and amongst the cases described below is one (Case 2) in which the giant cells entered into the composition of such a periosteal tumour, occurring in the femur, and we must therefore include this variety in the general classification of bone sarcomata.

It would lead me beyond the limit of this paper to attempt a review of all the different classifications; but the tumours which I have described I have named in accordance with a classification which Dr Dreschfeld has adopted in his lectures, and which is the outcome of an examination of nearly all the sarcomatous bone tumours which have been obtained from the Manchester Royal Infirmary during the last seven years. Broadly stated, we can distinguish between periosteal and central tumours—the former springing from the periosteum, the latter from the medulla or spongy portion; although it will be seen that one variety most likely springs from the compact portion of the bone.

Having regard to the naked-eye appearance and clinical features of the several forms, it will be found that the following are the more common varieties:—

Osteoid sarcoma,—a periosteal tumour, composed of spindle cells, true bone, and a quantity of fibrous tissue.

Osteo-chondroma,—a periosteal tumour, into the composition of which enters, besides the elements mentioned above, a good deal of cartilage.

Myeloid sarcoma,—often a myelogenic tumour, sometimes periosteal (such as epulis), usually devoid of ossification, and containing a large quantity of multinuclear cells (myeloplaxes).

Round-celled sarcoma (the encephaloid of Cornil),—a soft tumour, without ossification, springing from the medulla and spongy part of bone, or, as in some tumours of the upper jaw, from the more compact portion of bone. This tumour is of rapid growth, and often followed by secondary deposits in internal organs, and many of the so-called malignant myeloid tumours seem to belong to this class.

Angeio-sarcoma,—often developing from the medulla, occasionally, as in Case 2, from the periosteum. This

includes the variety of tumour called aneurism of bone, and is characterised by the preponderance of large blood spaces.

Alveolar sarcoma,—often affecting the bones of the skull and pelvis, and characterised by its malignancy. Many of the so-called cancers of bone belong to this group.

Besides these we have rarer varieties, such as—

The pure spindle-celled periosteal sarcoma (the fasciculated of Cornil).

The pure spindle-celled myelogenic sarcoma.

The pure round-celled sarcoma of periosteal origin (Gross).

The osteo-sarcoma of myelogenic origin.

The cysto-sarcoma,—of both periosteal and myelogenic origin.

It is rare, even in the above-given list, to find a tumour composed of only one kind of cell. The several varieties of cells (especially round and spindle cells) occur together, one kind, that which gives its name to the tumour, preponderating. In some tumours, however, we find such a mixture of cells, that to them the term *Mixed Celled Sarcoma* would be appropriately applied.

Lastly, many of these tumours undergo in parts degenerations (calcareous, fatty, and mucous) or hæmorrhage takes place into them, which alters their appearance, and has given rise to further complications in their classification.

I wish now briefly to relate the histology of some of the rarer forms, which I have examined with a view to study, not only the structure, but also, where possible, the development of some of the constituent parts, chiefly the bloodvessels and the bone.

For the material I have to thank the surgeons of the Infirmary whose names are mentioned in connection with the cases, and who have very kindly placed at my disposal the tumours which they removed.

Case 1.—The first case I have to report is one of periosteal sarcoma of the tibia of the osteo-chondroma variety. The patient from whom it was taken was under the care of Mr Jones last July, suffering from a tumour of the right leg, reaching from the knee-joint about six inches down the tibia. Amputation was performed in the middle third of the thigh,

and the patient recovered. Up to the present time no secondary tumour has formed.

On section the periosteum of the upper half of the tibia was seen to be replaced by a tumour, the fibula presenting its normal appearance. The tumour completely surrounded the tibia, and was not very vascular on section. Some parts of it were almost as firm as cartilage, others, which were the more vascular portions, were softer, the bone itself being slightly eroded in parts of its circumference, while in several points large blood-vessels could be seen.

On making a longitudinal section of the bone, several large spaces were found filled with blood-clot, and a few spiculæ of bone were observed in the tumour mass.

The portions of the tumour submitted to microscopic examination were—

1. The hard portion.
2. The soft portion.
3. The external portions.
4. The periosteum where it merged into the tumour.
5. The medulla of the bone.

I now give the description of the appearances of each of these parts.

The hard portion was found to consist of trabeculæ of cartilage in which the cells were not numerous; but as the trabeculæ neared the bone the cells were found to become branched, and assume the characters of bone corpuscles. Filling the intervals between the trabeculæ was a tissue consisting of large round cells about the size of cartilage cells, apparently destitute of a cell wall, their protoplasm being very coarsely granular, and each containing a large round nucleus and sometimes a bright nucleolus; in addition to these cells there were many others of a larger size and angular in form, having somewhat of the character of multipolar cells, but yet not myeloid cells. These contained, some one nucleus, others as many as four.

There also were seen numbers of round nuclei, which in several parts were observed to become surrounded by a small quantity of granular matter so as to form cells, which afterwards became similar to those already described.

The matrix of the tissue was granular, but occasionally fibrous.

A few bands of spindle cells were seen, which appeared to be produced by a lengthening out of the large round cells, these as they approached the spindle cells gradually becoming more fusiform. The cells, and principally the large round variety, were especially numerous at the borders of the trabeculæ of cartilage or bone, and were observed to become surrounded by a cartilaginous matrix, and to assume the characters first of cartilage cells, and afterwards of bone corpuscles. At these points numbers of small cells surrounded the larger cells, and it is conceivable that the smaller cells produced the matrix which entered into the formation of the cartilage and bone.

The bloodvessels in this part of the tumour were not very numerous, and were seen on section to be formed of bands of spindle cells similar to those already described, between which was a lumen filled with coagulated fibrin and blood corpuscles. The spindle cells at the outside of the bloodvessel merged, as already described, into the large round cells. In many parts of the section the bloodvessels were formed merely by spaces in the general tissue of the tumour, the cells at their borders being merely a little more closely packed. Large masses of extravasated blood were also found. In some parts the spindle cells were found to predominate.

The soft portions of the growth contained no cartilage or bone, but were composed of large round cells having a much larger nucleus than in the harder portion, some containing two or three nuclei. Small round cells and spindle cells were also seen, while the matrix was of a hyaline character. Hæmorrhages and numerous spots of mucous degeneration were found. The bloodvessels were here very plentiful, and their walls were formed merely of round embryonic cells. Outside them, in a few places, masses of coagulated fibrin were found.

At the borders of the growth, no capsule was found, but the large round cells were here very numerous, and infiltrated the surrounding tissue. The nuclei of the muscles at the borders of the tumour were proliferated, the fibres swollen, the stripes had disappeared, and the contents of the muscle tubes had a hyaline appearance, the muscle nuclei after proliferation assumed the same characters as the sarcoma cells, and merged into the general mass of the tumour. The original nuclei of the muscle became

the nuclei of the sarcoma cells, the protoplasm being formed apparently from the muscle substance.

In sections of the periosteum at the beginning of the tumour the origin of the cells could be clearly made out. The tissue corpuscles of the periosteum as they neared the new growth increased very much in quantity, their protoplasm becoming more abundant, their nuclei larger, until they finally merged into the sarcoma cells. The smaller round cells of the periosteum seemed themselves to form the nuclei of sarcoma cells, and gradually to surround themselves with protoplasm. The fibres of the periosteum seemed to disappear in the general tumour matrix, to some extent, however, being replaced by spindle cells, the connection between these and the fibres not being clearly made out.

The muscular fibres of the small arteries, which were found normal in some parts of the periosteum, were seen to become swollen, their nuclei to increase in size, and become rounded, the protoplasm also increasing in amount until the walls of the bloodvessel were formed by round cells with distinct nuclei resembling the ordinary cells of the tumour.

The medulla of the bone showed no changes.

Case 2.—This is a specimen of periosteal angeio-sarcoma, and was taken from a patient who was under the care of Mr Heath last summer, suffering from a tumour at the lower end of the left femur. Amputation was performed in the middle third of the thigh, and the wound healed favourably in due course; but after a little time the patient was readmitted to the hospital, the lower end of the stump having swollen very much, the skin reddened slightly, and the superficial veins distended. A return of the tumour was suspected, and an exploratory incision made, but the tissues being found healthy, no further steps were taken. The patient some time afterwards came under the care of Dr Dreschfeld, who diagnosed a secondary osteo-sarcoma of the lung. The patient has since died, and the diagnosis been confirmed.

The primary tumour is a pyriform mass situated with the larger end downwards at the lower part of the left femur. It extends from about four inches above the end of the bone to the upper part of the condyles, and occupies the anterior, inner, and

posterior parts of the bone, the external portions alone being free. On the inner side the tumour is covered by the thinned vastus internus and adductor muscles. On cutting into the tumour it is found to consist of soft pultaceous matter, in which are several large cavities filled with blood clot. Externally, it is covered by a thin layer of muscular fibre. Internally, the bone is seen rough and deeply corroded, while at the posterior part large osteophytic growths are observed. On sawing through the bone longitudinally, the diseased action is seen to have affected it from the epiphysis, which, however, is itself healthy, to a point corresponding to the upper limit of the tumour. The condyles themselves and their articular cartilages are unaffected. At the upper limit the periosteum is much thickened, and gradually merges into the tissue of the tumour, which evidently springs from the periosteum. The substance of the bone itself is reddened and soft, and in several parts shows cavities filled with pultaceous material. The medulla is surrounded by a portion of still hardened healthy bone.

The soft portions of the tumour were hardened in bichromate of ammonium, while the bony parts were decalcified in chromic acid.

The main mass of the tumour is seen on section to be made up of small round cells about the size of red blood corpuscles arranged in no definite order, and separated by a quantity of homogeneous intercellular substance. The cells seem to be devoid of cell wall, and possess a very large round nucleus filling almost the whole of the cell, while in the nucleus are seen several nucleoli. A much smaller quantity of spindle cells is found, each having a large oval nucleus, several nucleoli, and granules. The spindle cells are found scattered in small quantities among the round cells, and also arranged into bands, in the latter case being much more closely packed than the round cells of other parts of the tumour.

The bloodvessels of the tumour are very large, and have their walls made up for the most part of round cells similar to those of the remainder of the tumour, and without any definite arrangement. In certain portions of the tumour the walls of the bloodvessels are formed by spindle cells, and the round cells in approaching the bloodvessels gradually assume the characters

of the spindle cells. In no part is their found a bloodvessel of normal structure. A few myeloid cells are found, but they are scarce.

Near the circumference of the tumour the tissue is distinctly of a mucous type, the cells being large and branched, few in number, and imbedded in a hyaline structureless matrix.

Sections of the periosteum at the upper limit of the tumour show first the normal tissue of the periosteum with its bloodvessels, but as this is traced onwards, it is seen to become infiltrated by small round nuclei containing granules. The wavy fibres of the tissue give place to fine spindle cells, and the round nuclei become more plentiful, and now appear surrounded by a small amount of protoplasm forming round cells. Many of these become of an oval shape, and this type can still farther be traced into ordinary large spindle cells, while the round cells are continuous with the tissue of the tumour proper. Nearer to the bone the section shows large masses of extravasated blood. Trabeculæ of cartilage are also found, which become continuous with portions of the true bony tissue. The tissue between the trabeculæ is composed of small round masses of protoplasm, and large irregular cells with a large nucleus, surrounded by a granular protoplasm, some also having a double nucleus, the whole being imbedded in a scanty matrix, for the most part hyaline, but in some parts faintly granular. The small round masses are about the size of the nuclei of the large cells, and in some parts they become surrounded by a clear border of protoplasm, which, by tracing different cells, is seen to become granular, and increased in quantity until one of the larger cells is formed. As the tissue nears the trabeculæ of cartilage the large cells can be seen to pass into the form of cartilage cells, to become surrounded by a cartilaginous matrix, and so to merge into the substance of the trabeculæ, while on tracing the trabeculæ onwards, the cartilage cells are observed to throw out processes and become true bone corpuscles, the surrounding tissue also assuming a bony type. In addition to this phenomenon, ordinary bone formation by means of osteoblasts, these being apparently formed by the small round cells, could be seen, without, however, as far as I could make out, any erosion of cartilage cells. Proceeding towards the main mass of the tumour, the

trabeculæ of cartilage disappear, and small bloodvessels are observed, formed by walls of embryonic cells similar to those of the tumour. These gradually become much larger spaces, sometimes filled with blood pigment and in some parts spindle cells appear in their walls. Nearing the general mass of the tumour, the bloodvessels become more plentiful and larger until they form large irregular spaces, whose walls are still embryonic, and contain masses of shrivelled blood corpuscles, in the midst of these being small bands of embryonic fibrous tissue, continuous with the wall of the blood space, the tumour in this position, having a structure similar to that of an angeioma.

The medulla of the bone shows signs of irritation, but no trace of tumour tissue,

A section from the outside of the tumour near the muscles consists of mucous tissue, the same tissue being found in various parts of the tumour. The round cells of the tumour are found on approaching these spots, to throw out processes from their protoplasm, and to assume the characters of the cells of mucous tissue, the matrix becomimg more plentiful, hyaline, and in some parts faintly fibrillar.

Central Angeio-Sarcoma.

Case 3.—This specimen was taken from a patient for whom Mr Lund amputated the thigh some two years ago.

At the lower end of the left femur is a large tumour reaching from 7 inches above the internal condyle to 1½ inch below it. The greater portion of the tumour is situated to the inner side of the bone, but it also extends over the front and inner portion of the posterior surface, the external surface and the external portion of the posterior aspect being free. On the inner side, the tumour is covered by a thin layer of muscle, but beyond this no distinct capsule can be found. To the touch the tumour is firm but very friable, and does not yield on pressure any egg-shell crackling. On cutting into the tumour, it is seen to grow from the medulla of the bone. On the external part it is covered by a thin layer of bone, but on the inner posterior and anterior surfaces for about 3 inches, the whole of the bone has disappeared, and here the tumour has made its exit on to the surface. Above this point the whole of the external surface is found to be roughened, and its periosteum

much thickened, but no osteophytes are found. The roughened surface extends down to the upper limit of the cartiliginous surface of the knee-joint. The substance of the tumour itself is very friable, and of a dark red colour; no calcareous plates can be felt in it.

On microscopic examination, the main mass of the tumour is found to be made up of large accumulations of blood corpuscles bounded by embryonic round cells similar to those which form the tumour tissue proper, but in addition a few spindle cells can be found. The tumour tissue, which can only be observed with difficulty, is composed of large round cells, most of them without a cell-wall, and possessed of a large round nucleus, some having a double nucleus, and their protoplasm being exceedingly granular. The greater number of the cells are about the size of cartilage corpuscles, but many others are of a smaller size, but of similar characters. Separating the cells is a small quantity of intercellular substance, sometimes fibrillar in character, but for the greater part granular and structureless. A quantity of giant cells is observed, surrounded by the round cells, some of them angular in outline, but none possessing outrunners. Their protoplasm was very granular, but in no case could I see any trace of vacuolation or any tendency to development into bloodvessels. In this tumour I could not trace the development of the bloodvessels.

The periosteum itself showed no trace of morbid growth.

Periosteal Mixed Cell Sarcoma.

Case 4.—A woman was under the care of the late Mr Bradley last June, suffering from a sarcoma of the foot, which he removed by a Syme's amputation. The patient recovered after some sloughing of the posterior flap, and up to the present has had no recurrence of the tumour.

After removal, the tumour was found to occupy the anterior half of the foot, extending over the four inner toes. It was especially prominent on the dorsum and over the metacarpal bone of the great toe, but it was also apparent on the plantar surface. The tumour is soft but elastic, the skin over it being red and the superficial veins swollen. Immediately over the great toe the skin has been destroyed, and a mass of red fungations

thus producing the larger cells which were found, while several of the smaller cells became fused together so as to form the large cells with two or more nuclei. This would, according to some observers, be one step in the production of giant cells, which, however, are scarce in periosteal sarcomata.

In the growth of the central sarcomata, Gross and Ranvier assert that irritation is first set up in the marrow of the bone, causing a return to the embryonic state in which the giant cells are very plentiful. The giant cells may then multiply, or fresh ones may be produced by enlargement of the bone corpuscles, with proliferation of their nuclei.

The pathenogenesis of the two classes of tumours would hence be the same, and we see how they should differ in structure, the giant cells being so much more plentiful in the central than in the periosteal variety, for the adult tumour represents the embryonic type of that portion of the bone from which it develops. Clinically, we find that these tumours most frequently develop after some injury to the bone; and we have here the immediate cause of the production of embryonic tissue, for inflammatory growth is similar in nature to a sarcomatous tumour, differing from it however only in the fact that inflammatory tissue has a tendency to become organised, while a sarcoma continues to grow in its embryonic state.

But the neoplasm being once formed, it may increase in size, either by division and multiplication of its elements, or by change of the surrounding tissue into embryonic cells. Both these processes are seen in the sections I have described above. No doubt many of the large round cells with two or more nuclei are in process of division, and would ultimately have formed several smaller cells. Whether all the surrounding tissues may become sarcomatous must at present be considered doubtful. Several sections of the round celled sarcoma of the upper jaw showed distinctly that gland cells, although proliferated, still retained their epithelial type, and no connection could be traced between them and the sarcoma cells. It is not so, however, with the muscular cells. Dr Dreschfeld (*Lancet*, January 16, 1875), has described a case of sarcoma of the iris, in which he found that the sarcoma cells developed from the cells lying between the fibres of the involuntary muscle. Sokolow (*Virch. Archiv*,

vol. lvii. p. 39), also lays stress upon the development of sarcoma cells from intra-muscular nuclei. This same process I was able to trace in the voluntary muscular fibres in Case 1. Here it was clearly observed that the nuclei of the voluntary muscle first proliferated, and then surrounding themselves with part of the hyaline protoplasm of the muscular fibre, assumed all the characters of the surrounding sarcoma cells. In Case 1 similar changes were observed in the muscular fibres of the smaller arteries.

In the formation of the trabeculæ of bony tissue, commonly found in the periosteal sarcoma, and especially in the osteoid variety, there is apparently an anomalous process of osteogenesis. I have described above, how, in these tumours, the large sarcoma cells appear to change into cartilage cells, and these again pass directly into bone corpuscles, becoming surrounded by a true bony matrix, in which, however, the Haversian canals are deficient. This, which differs entirely from the generally accepted view of normal bone formation, has also been described by other observers. Thus, in the reports of cases at the end of a thesis on osteo-sarcomata of the limbs by Schwartz (Paris, 1880), there is a description by Vignal of the microscopic appearances of a periosteal sarcoma, in which he gives a similar account of bone development.

But perhaps the most important point to investigate in these tumours is the development of their bloodvessels. The sarcomata are always very vascular, but occasionally we meet with them in bone, presenting all the characters of aneurism. This usually occurs in the myeloid variety, but it is not by any means confined to it, and I have above reported, in addition to one of the central sarcomata, a periosteal sarcoma in which this phenomenon was present. Most of the pulsating tumours of bone have now been shown to be of sarcomatous nature, although some authors still maintain that a true aneurism of bone is possible, but rare.

The structure of these vascular sarcomata of bone has as yet been little worked at. It is necessary in investigating this matter to remember that hæmorrhages are extremely common in sarcomata, because of the delicate structure of the walls of the bloodvessels, and it is not always easy to distinguish between a hæmorrhagic focus in the tumour and a true sarco-

matous bloodvessel gorged with blood. In the *Path. Trans.*, vol. xxvi., Godlee reports a sarcoma in which he found a large blood cyst; but this he attributes to hæmorrhage. Billroth found in some bone sarcomata of the lower limbs, that the extreme vascularity was due to small aneurismal dilatations in the course of the vessels of the tumours. But the most important research on this subject is that of Monod and Malassez, published in the *Archives de Physiologie* for 1878. These observers take an entirely new view of the nature of the giant cells found in such quantity in these tumours. They believe that these cells are simply embryonic bloodvessels arrested in their development, remaining in a rudimentary state, but increasing enormously in size. It has been described by Klein, how in the embryo bloodvessels are formed by means of multinucleated cells. In the granulations of wounds, which are true embryonic structures, it has also been found that giant cells take an active part in the formation of bloodvessels. They have been observed in some quantity in granulations by Köster, and it has been found that these cells become vacuolated, that new blood corpuscles are found in their interior, either from the protoplasm or the nuclei of the cell, and that then the processes of the cell project into a neighbouring capillary, and becoming hollow, a communication is opened up between the blood current and the cavity of the giant cell, in this way a new bloodvessel being formed. Now, exactly the same process has been described by Monod and Malassez in myeloid bone tumours, and they say that in certain sarcomata they have observed every stage between the ordinary giant cell and a large blood cavity. Finding, however, that giant cells are not always seen in these vascular tumours, they assume that in these cases the whole of the giant cells have become transformed into bloodvessels. They term these vascular tumours angeio-plastic sarcomata. Still, although this explanation may hold good in some cases, I cannot believe that it is of universal application. Thus, the vascularity does not depend on the number of giant cells for the angeio-sarcomata, though more frequently central, are sometimes periosteal. Mr Heath's tumour (Case 2) is evidently of this nature. Now, although the periosteal sarcomata, like many other sarcomata, contain a certain quantity of giant cells, they are usually few

in number, and cannot account for the extreme vascularity observed in many cases. The explanation offered for the non-presence of giant cells in certain of these tumours is hardly satisfactory, for it would be expected that at the borders of the tumour some of these cells should be found in process of development, or if not, the tumours must have ceased growing, which, however, is not in harmony with clinical experience. It must also be remembered that the angeioplastic cells of Monod and Malassez are found in the medulla of normal bone, and are one of the sources of new red blood corpuscles. It is hence quite possible that they should be found in a tumour occupying the medulla, but having no tendency to excessive vascularisation. Therefore, unless they can be found in large quantities, at the growing part of the central sarcoma, and unless the bloodvessels and spaces of the tumour can be very distinctly traced to the multinucleated cells, we cannot safely admit, for that particular tumour, the explanation of Monod and Malassez.

I believe that another explanation may be found for many of these angeio-sarcomata. In the healing of wounds we find that, in addition to the giant cell formation of bloodvessels, we have columns of small round cells which join the neighbouring capillaries, and, becoming hollow, open out a new channel for the blood. So also in the sarcoma, new bloodvessels may form from the embryonic cells, and I have described how, in two of the cases, I could trace the transformation of the walls of the bloodvessels in the periosteum into embryonic tissue, and these bloodvessels afterwards into the large blood spaces of the tumour, the size of the vessels increasing *pari passu* with the changes in their walls. I should hence conclude that the blood cavities, at least in the cases I have examined, were due to the yielding of the young tissue in the walls of the bloodvessels before the pressure of the blood stream.

I have to thank Dr Dreschfeld for very kindly helping me in the examination of the tumours.

ON THE MORBID HISTOLOGY OF THE LIVER IN ACUTE YELLOW ATROPHY.

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CASES of acute yellow atrophy are of such rare occurrence, their pathology so far from being satisfactorily made out, and the lesions found so variously interpreted, that I wish to give briefly the result of the microscopic examination of the liver in two cases which I have had the opportunity of investigating. The cases are specially interesting, for while one ran a very protracted course, the liver being very much diminished, and showing both yellow and red atrophy, the second case ran a most acute course, the liver being enlarged from old-standing fatty disease, and showing simply yellow atrophy without any admixture of red atrophy. I had thus the opportunity of comparing the lesions of the earlier with those of the later stages of the disease, and important differences were found.

Case 1 was that of a lady under the care of my friend Mr Cullingworth, who carefully observed the clinical features of the case, and has described them in the *Med. Times and Gaz.*, March 5th and 12th, 1881.

The duration of the case was nearly four weeks; it commenced with symptoms of simple catarrhal jaundice, which existed for three weeks, and were followed by typical symptoms of acute yellow atrophy (hæmorrhages, nervous symptoms, diminution of liver-dulness, &c.) Noteworthy points in the case were the absence of both leucin and tyrosin from the urine, and the presence of urea in a fairly normal quantity.

The *post-mortem* examination was conducted by Mr Cullingworth and myself, and the following is a brief extract from the notes taken :—

Post-mortem, sixteen hours after death : rigor mortis in limbs well marked.

Abdomen.—Peritoneum normal, intestines normal, hæmorrhagic spots throughout mesentery and beneath serous covering of the intestines.

Liver unseen until the ribs were raised; it was free from adhesions, and had fallen away from the ribs; its lower border in the nipple-line corresponded to the seventh rib, the lower border of the left lobe did not reach the ensiform cartilage. The bile ducts were free; the gall bladder contained a small quantity of green bile. The liver was very small; its surface smooth, and capsule easily wrinkled. The weight of the liver was 677 grammes, the thickness 7½ cm., breadth 24 cm., length 29 cm. On both upper and lower surface were a large number of orange-yellow patches, of various sizes and irregular in outline, not raised from the surface; these were seen on section to extend into the liver substance, and to be irregularly distributed and unconnected with bile ducts; numerous smaller yellow patches were seen throughout the liver; the rest of the liver was of reddish colour, of uniformly soft consistence, showing the lobules of the liver much smaller than normal; the yellow parts passed in some places gradually into the red parts, in other places they were more circumscribed; in the yellow portions the outline of the lobules could not be made out.

The lungs showed no noteworthy change.

The heart studded with hæmorrhagic spots on the pericardial surface, both its ventricles empty; blood in the large veins, dark and fluid.

The kidneys (weight of one being 75 grammes) showed no changes, except that they were tinged by the biliary colouring matter.

The other organs showed nothing abnormal.

The microscopic appearance of the liver varied according to the parts examined.

In the parts which, to the naked eye, had a distinct yellow appearance, the changes were almost entirely confined to the liver cells, and consisted in fatty degeneration of them; in the red parts, which to the naked eye, except for the smallness of the lobules, looked fairly normal, the appearance was different and more complicated.

Considering the yellow patches first, it was found that in those least affected the lobules had already lost their outline for the most part, whilst the interlobular vessel sseemed compressed, but not otherwise altered. The liver cells were swollen, their

nuclei indistinct, and their contents a mass of fat granules, which gave, with osmic acid, the characteristic reaction.

In parts, where the changes had gone further, only a few rows of liver cells with distinct outlines were seen; while the rest consisted of multitudes of fat granules, collected in larger masses, and held together by the remains of the liver stroma; many smaller collections of fat granules were seen corresponding in size and outline to liver cells, but no nuclei were visible in them.

In the parts most affected the liver tissue had completely disappeared, and the microscope simply revealed masses of fat granules, a little pigment, and empty spaces, showing shreds and fibres, evidently the remains of the liver stroma.

The parts which, to the naked eye, seemed to form the transition from the yellow to the red portions, gave a very similar microscopic appearance, except that amongst the debris and in the stroma a number of small embryonic cells, of the size and character of leucocytes, were seen, easily recognised by their taking the logwood staining well, whilst the degenerated mass remained unstained.

The red patches showed a different microscopic appearance. In stained preparations, examined with a low power, the outlines of the liver lobules could be made out with ease, owing to a cell infiltration round the outer lobular vessels extending for some distance along the spaces separating the lobules, and to the presence of numerous biliary ducts filled with epithelial cells. The peripheric part of each lobule showed masses of highly refractive cells arranged in the form of tortuous canals, whilst the greater portion of the lobule had a granular appearance. Under a high power, it was seen that the cell infiltration round the portal vessels consisted of leucocytes and embryonic tissue. In some places this had already become firmer, and assumed a more fibrous character. Besides this, the interlobular spaces showed numerous biliary canals, lined by a cubical epithelium tinged with biliary colouring matter. The peripheric part of the lobule consisted of liver cells, shrivelled and diminished in size, homogeneous in appearance, and with no visible nucleus; the cells were arranged in parallel rows, looking like small tortuous canals, and, at the periphery of the lobule, seemed

often to be directly continuous with and to pass into the biliary canals. When seen in transverse sections these rows of atrophied liver cells had the closest resemblance to bile ducts cut across. The cells were arranged in a circle, and in the centre of the lumen thus left small masses of bile pigment were seen. The gradual change of these liver cells into distinct epithelial cells, however, as seen in cases of biliary cirrhosis, could not be made out. Preparations from the red portion, stained deeply in logwood, showed, besides these appearances, some other points, namely, numerous small cells with distinct nuclei, like embryonic cells, in different parts of the lobule, often closely adherent to shreds of thickened fibrous tissue; and collections of small round cells, with large nuclei, occurring both in the central and also peripheric part of the lobules. These collections of cells seemed to be situated in distinct canals, with a fine lining membrane, and had the closest resemblance to dilated biliary ducts.

Lastly, numerous free nuclei were seen in different parts of the preparation.

The central vein of the lobule in the red portions of the liver had its wall considerably thickened, and was surrounded by a considerable mass of fine fibrous tissue, containing in its meshes embryonic cells.

In no section were any crystals of tyrosin or leucin observed.

Koch's method for detection of micro-organisms was applied to numerous sections, but gave negative results.

The kidney showed the so-called cloudy degeneration of the epithelium of the convoluted tubes, some of the glomeruli had assumed a hyaline condition, and numerous biliary granules were found in all parts of the organ. Otherwise it showed no changes.

Koch's method applied to sections from the kidney and spleen (which, beyond cellular infiltration of its pulp, showed no changes), gave here also only negative results.

Case 2 was a patient who had recently been admitted into the Manchester Infirmary by my friend and colleague Dr Ross. The patient had only been suffering for two days when admitted, and his symptoms consisted of slight jaundice, hæmatemesis, great debility and depression, with delirium. He became very

delirious after admission into the hospital, had another attack of hæmatemesis, and died in a few hours. The history of the patient showed that there was no acute poisoning or any previous illness.

On *post-mortem* examination, the stomach was found full of coagulated blood; its mucous membrane blood-stained, but not otherwise altered. No rupture of any bloodvessel in the stomach could be detected. Ecchymoses beneath the serous membrane of the intestines and beneath the integuments of the thorax.

The liver was large, and weighed 4 pounds 4 ounces; its surface smooth, the capsule neither wrinkled nor thickened. On section, the organ was found somewhat soft in consistence, the greater portion having a greyish lemon colour, with the outlines of the lobules but little marked; other parts of the liver had a light brownish and more natural appearance, and here the lobules were well defined near the under surface of the liver, but within its substance and surrounding the hepatic duct, there were several large patches (the largest measuring 1 inch in one, and 1½ inch in another, diameter) which were of deeper colour, slightly raised from the surrounding tissue, of soft consistence, and rather well defined from the surrounding parts.

In no part of the liver could any red patches, such as seen in the first case, be detected.

There was no obstruction to the bile ducts, which contained a little gelatinous mucus.

The blood was dark and fluid.

The microscopic examination was conducted both on the fresh and hardened specimens of the liver. Some parts of the liver were perfectly normal in structure, but the greater portion, which to the naked eye had a greyish lemon colour, was found in a state of fat infiltration, the liver cells containing one large or several small fat drops, the cell nucleus, however, still being very distinct.

The deep yellow patches gave a different appearance. The changes observed here corresponded in a great measure to those seen in the yellow patches of the liver from the first case; thus the interlobular spaces were free from cell infiltration, there was no increase in the biliary ducts, and the greater part of the liver cells had disappeared from the lobule, and had been

replaced by a granular fatty detritus, with free nuclei, shreds of fibrous tissue, and what appeared to be dilated blood capillaries. But besides these changes, in a number of lobules and especially in their peripheric parts, there were seen liver cells which had become completely altered in appearance; they were much smaller, had one or two large nuclei, often also a nucleolus, whilst the rest of their protoplasm was homogeneous, and free from granules. These cells resembled much more the epithelial cells in epidermis than liver cells. On the one side these epithelium-like cells gradually passed into normal liver cells; on the other side, towards the centre, they seemed to break up into granules, their nucleus remaining intact for a time.

Koch's method gave equally negative results in this case when applied to sections of the liver in the fresh state.

Before considering the bearings which these cases have on the pathological anatomy of acute yellow atrophy, we will briefly state the main points about which authors at present disagree.

1. As regards the icterus, many believe it to be of the hepatogenic, others believe it to be of the hematogenic kind.

2. While all are agreed that the chief lesion in the liver, whether acute liver atrophy be considered a general disease (as most observers believe), or primarily a local disease, consists in a fatty degeneration of the liver cells, some writers (*e.g.*, Winiwarter, *Wien. Med. Jahrb.* 1872), think that the first change consists in an inflammatory process in the interlobular areolar tissue, which only secondarily causes fatty degeneration of the liver cells. Again, according to Levitski and Brodowski (*Virch. Arch.*, vol. lxx. p. 421), there is, prior to the cell degeneration, a cell proliferation in some parts of the liver lobules, these observers having seen numerous liver cells three to four times smaller than the normal liver cells in those parts of the liver parenchyma which had not yet undergone degeneration.

3. As to the relation of the red to the yellow atrophy, most pathologists now believe that the red atrophy is only a more advanced state of the yellow atrophy, and is found in cases which run a slow course (Zenker, Perls, &c.); while Klebs, on the other hand believes the two to be essentially different processes.

4. The red atrophy is characterised by a more complete

disintegration of the liver cells, by the presence of an interlobular embryonic tissue, and of rows of cells resembling glandular tubes, supposed by some to be proliferating biliary ducts (Cornil and Ranvier), by others to be the surviving columns of hepatic cells (Thierfelder, in *Ziemmsen's Cyclopædia*, vol. ix. p. 254.)

5. Lastly, some observers (Waldeyer, Zander) have discovered bacteria in the atrophied liver. (In Zander's case, however, the autopsy was not performed until 58 hours after death).

Considering now our own two cases in relation to these several points, we see—

1. As regards the nature of the jaundice. In the first case, it resembled at the commencement of the disease simple catarrhal jaundice. At the autopsy, however, the larger bile ducts were found free from catarrh, and the smaller ones, wherever examined, contained nothing abnormal, with the exception of the small interlobular canals, which were filled with epithelial cells resembling the condition found in hypertrophic cirrhosis. But it is now established that such a change need not necessarily produce jaundice (see my paper on Cirrhosis of the Liver in a recent number of this *Journal*[1]). In the second case, jaundice developed only within the last few hours of life, and no obstruction to the bile passages, not even proliferation of the smallest bile ducts, was seen. I look upon the jaundice then to be of the hematogenic character, and certainly all the other symptoms observed correspond well with this view.

2. The second case directly negatives Winiwarter's view; here we had to do with a very incipient case of acute yellow atrophy, which ended fatally so rapidly because the bulk of the liver was in a diseased state from fat infiltration. Nowhere, however, could there be seen any deposit of embryonic tissue, either in the circumference or within the affected acini. Besides the fatty degeneration, I have above described a peculiar change of the liver cells into epithelium-like cells. Unlike Brodowski and Levitski, I believe these cells to represent merely a form of atrophy, and not to be due to proliferation. I have seen such cells in other chronic pathological conditions of the liver; and both Kelsch and Kiener, Brieger and others, have described this

[1] Vol. xv. p. 69.

peculiar change in the monolobular cirrhosis, where these atrophic liver cells were observed to pass gradually into the true epithelial cells of the biliary ducts. I have failed to trace such a continuation here, and indeed the biliary ducts showed no proliferation.

The large weight of the liver in the second case is undoubtedly due to the fact that we had to do here with a fatty liver of old standing. Thierfelder (*loc. cit.* p. 246) quotes a similar case, observed by Liebermeister, where the liver weighed 1520 grammes, and another, observed by Frerichs, where there was, besides fat infiltration, cirrhosis also, and where the weight amounted to 2100 grammes.

3. Both cases strongly support the view that the red atrophy appears later in the course of the disease, and that in it the degeneration has still further progressed, and that it is not a separate disease. We find it altogether absent in the second case, which was of very short duration, and in the first case, as will be seen from the description given above, the yellow patches gradually pass into the red ones.

4. The different constituents described under this head as seen by many recent observers in the red portion, were noticed also in our first case. The cellular infiltration of the interlobular spaces, and its gradual change into embryonic fibrous tissue, leaves no doubt that we have here a process of an inflammatory kind subsequent to the fatty degeneration of the liver cells. The presence of a number of lymphoid cells amidst the fatty degenerated interlobular masses, was also seen and described by Klebs. Whether they are emigrated leucocytes, whether they go to form fibrous tissue (like the interlobular cell masses), or whether they serve regenerative purposes, is mere conjecture. As to the rows of cells which have a glandular arrangement, it will be seen that I have described two sets,—one consisting of shrivelled and atrophied liver cells, the other consisting of dilated biliary tubes, filled with epithelium in the midst of degenerated liver cells. The existence of these two kinds would explain the discrepancy that exists amongst different observers. Whether the atrophied cells eventually join or change into the numerous biliary ducts seen at the periphery of the lobule, as is the case in the monolobular

cirrhosis, could not be made out very clearly from the preparations. On the other hand, there can be little doubt that the numerous biliary canals in the interlobular spaces, and the dilated intralobular biliary capillaries filled with epithelium like cells, are evidences of a proliferating process.

5. As seen from the description, the search for microorganisms in the liver, kidney, and spleen gave negative results.

THE REL THE MUSCLE AND ITS CO

THEODORE CASH, M.D.

(With FIGURES.)

ALTHOUGH it is only in recent times that we have learnt to avail ourselves of a "graphic method" for purposes of accurate demonstration and measurement of physiological processes, there have not been wanting amongst the older physiologists many who have attempted, by an association of observation and calculation, to arrive at an estimate of the length of a single muscular contraction in various animals. Thus, Haller[1] calculated, from noticing the number of steps taken by a rapid runner in a given time, that the quickest contraction of which the rectus femoris was capable might be the $\frac{1}{250}$th second in length, whilst in the dog it would not be more than the $\frac{1}{400}$th. He calculated that in the most rapid speech the styloglossus might complete a contraction in the $\frac{1}{500}$th second, whilst in the case of the pigeon, for a movement of the pectoral muscles, less than $\frac{1}{800}$th second would be required. Valentin[2] concluded, from observing an adept pianist, that a flexion or extention of the index finger lasted $\frac{1}{4}$th to $\frac{1}{8}$th second, and that in the case of a quick runner the contraction of the muscles of the leg would occupy the $\frac{1}{80}$th second; from the height of the tone caused by the wing vibration of an excited fly, he estimated that the length of a single contraction of the wing muscles might be of the value of $\frac{1}{8000}$ second.

Weber[3] studied the speed with which contraction occurred, after he had admitted a current from a magneto-galvanic rotation apparatus for a short period. From the results he obtained, he pointed out the essential differences of the striated or animal muscular fibre, on the one hand, and the unstriated or organic muscular fibre, on the other; and he further established the fact, that amongst the structures possessed of organic fibre, wide variations of rapidity of contraction in response to stimulation occur.

[1] *Elementa Physiologiæ*, 1762, vol. iv. p. 481.

[2] *Lehrbuch der Physiologie des Menschen*, 1844, vol. ii. p. 165.

[3] *Handwörterbuch der Physiologie*, von Rudolph Wagner, 1846, vol. iii. section ii. p. 39.

"The slowest movement," he says, "was shown by the ureter and gall bladder, visible contractions in which could only be caused after they had been subjected to the stream for a long time. The effect on the cæcum of the rabbit and on the stomach is more rapid. Still more active is the response of the iris (in as far as it possesses organic muscular fibres), and of the urinary bladder. Incomparably quicker are the movements of the vasa deferentia, and, above all others already mentioned, of the œsophagus. Finally, amongst all organic muscles, the heart has the most active and energetic movements, and contraction therefore succeeds most rapidly to stimulation; thus it shows to a certain degree an approximation to the rapid and powerful movement made by animal (striated) muscles, whilst its fibres are allied to those of animal muscle." Weber remarked, that certain organs possessing in individual animals striated muscular fibre, reacted similarly to the striated muscles of the extremities. It was thus in the case of the œsophagus of the dog, the iris of the bird, and the intestine of the tench (*Tinca chrysitis*).

Subsequently to Helmholtz's demonstration of the manner in which a single muscular contraction could be measured, Marey[1] undertook some experiments on the comparative characters of muscle curves in the case of different animals. He has shown that the pectoral muscles of the pigeon have shorter contractions than rabbit's muscles, whilst the latter again are more rapid than those of the frog; further, that the contraction of different muscles in the same animal may have between themselves varying values, as in the relatively longer action of the hyoglossus than of the gastrocnemius of the frog.

The valve muscle of the anodonta was shown by Fick,[2] not to reach its maximum of contraction in less than 10 seconds, and Ranvier demonstrated the great variation which exists in the reaction of the red and white muscles of the rabbit respectively.

Spite of all these researches, it seemed to remain dubious whether we were justified in still supporting Weber's functional division into organic and animal muscular fibre; and it was with the view of contributing a little towards the solution of this question that I undertook, at the suggestion of Professor Hugo Kronecker

[1] *Du Mouvements dans les Fonctions de la Vie*, 1868.

[2] A. Fick, *Beiträge z. Vergleichenden Physiologie der irritabelen Substanzen*, 1863.

(to whom I desire here to return sincere thanks for much kindness), the experiments the results of which I shall proceed to record. My observations were made on the frog (*Rana esculenta*), land tortoise (*Testudo europœa*), and rabbit.

The nature of the ventricular contraction of the frog's heart, and the influence of surrounding temperature upon its rhythm, have been carefully studied; and it has been shown, that whilst the length of a systole and diastole at room temperature has the value of 1″ to 1·5″, by cooling to 0°, the united duration of the two phases may be no less than 6·0″, and by heating to 30°, no more than 0·5″. Helmholtz has estimated the value of a single contraction of the gastrocnemius at about 0·1″.[1]

To facilitate comparison, I shall place in a tabular form the relative lengths of the contraction of various muscles of the frog. The figures are the averages of values obtained from numerous experiments.

1.	Musculus	hyoglossus,	0·205–0·3″
2.	„	rectus abdominis,	0·17″
3.	„	gastrocnemius,	0·120″
4.	„	semimembranosus et gracilis,[2]	0·108″
5.	„	triceps femoris,	0·104″

The cardiac cycle, in the case of the tortoise, lasts from 2·5″–3·2″; and for comparison with this, I give another series of lengths of contraction of striated muscles, taken from the trunk and limbs of the animal.

1.	Musculus	pectoralis major,	1·8″
2.	„	gluteus (alter),	1·6″
3.	„	palmaris,	1·0″
4.	„	gracilis,	1·0″
5.	„	biceps brachii,	0·9″
6.	„	splenius capitis,	0·9″
7.	„	triceps brachii,	0·8″
8.	„	retrahens capitis et colli,	0·75″
9.	„	extensor communis dig,	0·75″
10.	„	semimembranosus et adductor,	0·6″
11.	„	omohyoideus,	0·55″

[1] L. H. Bojanus, *Anatome Testudinis Europœæ*, Vilnæ, 1849.

[2] Prof. du Bois-Reymond has advocated the name M. gracilis, instead of that of Adductor magnus, previously used by himself, Heidenhain, and Wundt, or that of Rectus internus major, proposed by Ecker, in his *Anatomie des Frosches*.

In the case of the rabbit, the cardiac cycle has a value of about ⅓rd of a second (·33″), whilst the muscles of the calf of the leg give the following values for a maximal contraction:—

1.	Musculus soleus (red), ...	1·0″
2.	„ gastrocnemius mediatis (white),	0·25″

So that in this animal a complete cardiac cycle is decidedly shorter than a contraction of the soleus.

I must here point out, that the length of the muscle curve as given in these tables, does not include the final and slowly occurring relaxation (disappearance of Nachwirkung) of the stimulated fibres; did it do so, I should give no idea of the active phase of the contraction, for while this lasts in the case of a tortoise muscle up to 1·8″, some amount of contraction after the active phase is over may be observed for 6″–8″. The length of the active contraction is also within certain limits a variable figure; as it is subject to many influences, potent to cause deviation, as in change of temperature, the burdening or afterburdening of the muscle, *e.g.*, change in tension, and its condition of weariness from repeated stimulation, &c. Further, the time of the year at which the frog for experimentation is chosen has a great influence, not only upon its irritability and "fitness" for action, but also upon its motility.[1]

Thus, muscles taken from a March frog may give us values very similar to those of a summer tortoise. As examples of these, I give the following figures, which, though they have no absolute constancy, show the general relationship of the different muscles to one another to be maintained.

Length of contraction of frog's muscles (March), after the animal had been kept in a room at 18° C. for some days.

1.	Musculus hyoglossus, ...	0·8″–1·0″
2.	„ gastrocnemius, ...	0·4″–0·5″
3.	„ semimembranosus et gracilis, .	0·3″–0·36″
4.	„ triceps femoris, . . .	0·25″–0·4″

(In this series the great length of contraction may in part be accounted for by the extreme cold to which the animals had for a long time been subjected before their capture).

[1] H. Kronecker, "Ueber die Ermüdung und Erholung quergestreifter Muskeln" —*Arbeiten aus der Physiolog. Anstalt* zu Leipzig, 1871.

But beyond the mere consideration of the duration of the curve of any muscle, is the study of the *form* of that curve. Many curves have forms at once so constant and so peculiar that they may readily serve as indication of the muscle, or species of muscle, from which they are derived.

I shall proceed to a brief description of various muscle contractions, and endeavour to render the subject more intelligible by inserting cuts, taken from photographs which were obtained from the original curves.

Du Bois-Reymond[1] has drawn attention to the peculiar and complicated construction of the gastrocnemius of the frog. He points out that the muscle bundles of varying lengths run obliquely to their insertion, and that therefore they are unequally tensed by a weight applied to the tendo achilles, and must participate unequally in raising it. Still, as this muscle is readily isolated and most easily preserved with a considerable length of nerve in connection, and as its powerful tendon with an associated sesamoid bone renders attachment to the lever a simple matter, it has remained in favour to the present time, and has even received a special recommendation from the fact that it was upon the gastrocnemius that Helmholtz studied first of all the course of a simple contraction.

In order to represent graphically the course of contraction of frogs' muscles, I employed the Du Bois-Reymond spring myograph. It will be observed from the character of the waves of the tuning fork, which yielded 143 D.V. per second, as well as from the curve itself, that the decline in velocity of the projected slide is very rapid, so much so in fact that two double vibrations about the region of the 14th or 15th may have together only a corresponding lineal value to a single one during the latent period. Had I chosen, however, a more powerful spring for the propulsion of the plate, I should have failed to obtain a complete registration of the curve.

The weight of the lever employed was slightly less than 10 grms., and to this such weights were added as seemed desirable, they in all cases being freely suspended.

Terminal waves due to elasticity occurring after the primary

[1] Du Bois-Reymond, "Ueber das Gesetz des Muskelstroms mit besondern Berücksichtigung des Musc-Gastroknemius."—*Gesammelte Abhandlungen*, Bd. ii.

contraction are omitted for sake of simplicity, and because their representation in no way affects the subject under consideration.

Stimulation by a single induction shock of maximal strength, as carefully determined by adjustment of the secondary coil of a Du Bois-Reymond's apparatus, was conducted either to the muscle or to its nerve at pleasure. The fresh muscle lifting weights within its compass is modified in the altitude and length of its contraction according to the extent of the weight applied; the greater the weight the less the altitude and the shorter the curve. But it will nevertheless be seen that, though in these respects the curve is modified, it retains its original character as in fig. 1, in which three curves obtained from the gastrocnemius under varying weights are represented.

Fig. 1.

Curve of maximal contraction of gastrocnemius of frog, stimulated by an opening induction shock. Weighted with 20, 30, and 50 grms.
A double vibration of the tuning fork is equal to $\frac{1}{15}$.
The perpendicular line close to the name of the muscle marks the time of stimulation. The lever multiplies the actual contraction by $3\frac{1}{2}$ in figs. 5–6.

The semimembranosus and gracilis together form a considerable mass of fairly parallel fibre terminating in an ill-defined though easily separated tendon.[1] Their pelvic origin is broad, and admits of easy suspension; care must, however, be taken in separating them from below not to disturb the motor nerve-fibre passing from the sciatic to the lower part of the upper third of the semimembranosus.

Fig. 2 exhibits the nature of the curve and the effect of variations in burden upon this group.

[1] Wundt., *Die Lehre von der Muskelbewegung*, 1858.

The complex muscle, triceps femoris, largely employed by Kronecker[1] and other German physiologists, yields the third series of curves, and in this case as in that of the gastrocnemius, it will be seen that, though the weight is increased from 20 grms. in the outermost to 50 grms. in the innermost curve, the essential characters of both contractions are the same.

Fig. 2.

Semimembranosus gracilis of frog, opening shock, maximal contraction. Weighted with 20 and 30 grms. Time marker as in fig. 1.

It has already been mentioned that Ed. Weber[2] has demonstrated the relatively greatly prolonged curve of the hyoglossus in regard to the muscles of the limbs in the frog. He employed this muscle in his experiments on elasticity and the condition of contraction of striated muscle fibre. Small increase of burden rapidly reduces the altitude and length of the curve of this muscle,

Fig. 3.

Triceps femoris of frog, opening shock, maximal contraction. Weighted with 20, 40, and 50 grms. Time marker as in fig. 1.

which is from its extreme thinness little fitted to act as a burden-raiser. Thus, in fig. 4, we see that, whilst under 10 grms., the con-

[1] Kronecker, *Arbeiten aus der Physiolog. Anstalt* zu Leipzig, 1871.

[2] *Muskelbewegung.* Rud. Wagner's *Handwörterbuch der Physiologie*, 1847.

traction is extensive and of great length, an addition of 5 grms. considerably reduces the maximal, and a total of 20 grms. permits only a low and relative short (19·5 D.V.) contraction. We see from this figure that the return of the pen to the original rest position is only incomplete when a very small weight (10 grms.) is applied to the tendon. The lever is detained by the tenacity

Fig. 4.

Hyoglossus of frog, opening shock, maximal contraction. Weighted with 10, 15, and 20 grms. Time marker as in fig. 1.

of the muscle, aided by the slight friction always existent between pen and plate. The curve is, however, not only lowered in altitude by relatively large weights, but also markedly shortened in its continuance.

If we group together (fig. 5) the curves of the muscles, which we have briefly considered, we see more readily the relative features of the individual contractions. It will be noted that the

Fig. 5.

One maximal contraction taken from the gastrocnemius, semimembranosus, and triceps of the same frog; the time of stimulation is the same for all. Weight, 10 grms. Time marker as in fig. 1.

gastrocnemius has an entirely different course from that exhibited by the triceps and gracilis with semimembranosus. The two complex muscles last named have a close similarity in their

mode of contraction; they reach their maximal altitude immediately after they have passed through the first half-time division or their total activity; whilst the gastrocnemius takes two-thirds of its entire cycle to contraction, and only one-third to elongation.

The second group (fig. 6) has been introduced here to point the contrast between the slowly-moving muscles of the trunk—rectus abdominis and hyoglossus—and the rapidly-acting vigorous muscles of the extremities.

It is obvious from a consideration of these, that not only is the nature of decline of the curve as influenced by the different methods of burdening which may be employed, a very important factor in the total value of the contraction, but that the period of developing energy varies in a surprising manner. Thus the maximum of contraction of the hyoglossus is only

Fig. 6.

One maximal contraction taken from the gastrocnemius, triceps femoris, rectus abdominis, and hyoglossus of same frog. Weighted—the two first with 20 grms., the two last with lever. Time marker as in fig. 1.

reached the instant that the triceps is regaining the abscisse; whilst the rectus abdominus, spite of the coincidence it at first shows with the course of the hyoglossus, reaches its maximum, and declines much sooner than the last named muscle. The gastrocnemius, whilst showing a very flattened upward course by reason of its rapid decline, joins the abscisse much before the rectus. The triceps femoris, in its steep ascent and yet steeper decline, equals the semimembranosus-gracilis group, and exceeds in the former respect all other muscles.

As the most active muscle of the tortoise is slower than the least active of the frog, it became necessary, for the examination of the muscles of this animal, to abandon the spring myo-

graph, and to employ in its place, as recording apparatus, a cylinder myograph with a moderate speed of rotation. A second marker in connection with a clock wrote beneath the muscle lever, and served to control the length of the contraction and the velocity of the drum; where a more exact measurement of time intervals appeared advisable, a point connected with a metal arm of known speed of vibration was applied beneath the curve.

As in the case of the frog's muscle, so here we find that increasing burdens influence markedly the length and altitude of the contraction, but to whatever extent this may be the case the form of the curve of a tortoise muscle holds to its essential details within very narrow limits of variation.

Fig. 7 shows the mode of reaction to direct and maximal stimulation of a long, thin, paralleled-fibred muscle—the omo-

Fig. 7.

Maximal curves of contraction of the muscle omohyoid of the land tortoise. Weighted with 10, 30, and 50 grms. Stimulation direct. Lever multiplies actual contraction 3¼ times in figs. 7–10. The long strokes mark seconds, the dashes half seconds, and the dots one-tenth of a second.

hyoid. The rapidity with which this muscle reaches its maximum of contraction will be readily recognised, and it will be further seen that an additional burden causes a considerable deterioration in the altitude, which falls equally from the first and second summits for each 20 grms. applied.

The pectoralis major (fig. 8), a very powerful, thickly-built muscle, presents a marked contrast to the last in its behaviour when exposed to considerable variations in burden. The difference in the altitude attained is inconsiderable (4·5 mm.) when

the original weight of 20 is increased to 120 grms. The rapidity of contraction of the muscle, though marked in contrast to most of those of the extremities, is yet inferior to that of the omohyoid. It will be observed that stimulations under 80 and 120 grms. have caused contractions exhibiting more gradual decline than in the case of the curve obtained under 20 grms., thus illustrating the fact which Marey[1] has demonstrated with frog's muscle, that expansion after contraction follows more slowly when a muscle is hindered, by some cause which it cannot overcome, from reaching its possible maximum.

There is a close analogy, both in form and reaction, between the omohyoid and the semimembranosus on the one hand, and between the pectoralis major and the gluteus maximus on the other; the former pair having parallel fibres producing a curve

Fig. 8.

Pectoralis major of land tortoise. Weighted with 20, 80, and 120 grms. Time marked as in fig. 7.

of early maximum and with a sharp summit, indicating that the action at its maximum is not long sustained, whilst the latter pair have fan-shaped bellies and converging fibres, which contribute to a contraction of considerable sustenance at its maximum, as indicated by the plateau on the summit of the curve.

A contrast group of tortoise muscles is seen in fig. 9. Here the omohyoid has the most rapid action; it reaches its maximum long before the palmaris, and from half a second to one-third of a second before the pectoralis major or gracilis. The function of this muscle, to draw back the head rapidly at the approach of danger within its sheltering carapace, is thus well represented.

[1] *Du Mouvement dans les Fonctions de la Vie*, 1868, p. 363.

The action does not, however, require to be a sustained one; it is the instant accomplishment of a sudden necessity, and we accordingly find that there is but short continuance of maximal shortening. The protrusion of the head is a much slower operation, and appears to depend for its performance chiefly on short oblique fibres which come successively into action as the movement outwards progresses.

The pectoralis major, having for its function the propulsion

Fig. 9.

Maximal contractions of the muscles pectoralis major, omohyoid, gracilis, and palmaris. Weighted with 30 grms. Time marked as in fig. 7.

of a heavy animal, commences its systole with an energetic approximation of its fibres, and remains for a considerable time in a condition of powerful contraction. The gracilis (flexor of the hinder extremity), a much feebler muscle, contracts and extends less rapidly. The palmaris (a short powerful muscle), adapted in the tortoise to pushing movements, is very slow in its contraction, but even slower in its relaxation.

The curves represented in the next figure (fig. 10) illustrate

Fig. 10.

Maximal contractions of the muscles gluteus, semimembranosus, biceps brachii, and triceps brachii of the land tortoise. Weighted with 30 grms. Time marked as in fig. 7.

the course of contraction of four other muscles of the tortoise. It has been already remarked that the semimembranosus closely resembles the omohyoid, and the gluteus maximus the pectoralis major, whilst the biceps brachii shows a near relationship to the gracilis of the hinder extremity. I was unable to make sufficient observations on the latissimus dorsi to decide accurately the form of its curve, but it seems to show a close correspondence with that of the triceps brachii, and is slightly, though distinctly, removed in type from the gracilis group.

I must close this part of my subject by expressing the desire that the points of difference in the character of the curve which I have endeavoured to emphasise should be regarded as indications of variation in muscles widely separated, both in form, distribution and function, from each other, and not that the figures or curves which have been introduced should be regarded as

Fig. 11.
Gastrocnemius medialis of rabbit (white muscle). Weighted with 50, 100, 300, and 500 grms. Maximal contractions. Lever multiplies by 2½ in figs. 11 and 12.

absolute representations and values. An accurate consideration of the influence exercised, in the case of individual muscles, by temperature, and more especially by burden, though necessary to the comparison of function as demonstrated by the modified curve, would lead us into a dissertation whose profit could scarcely be proportional to its dimensions.

The interesting results of Profs. Kronecker[1] and Stirling, obtained in investigating the course of contraction of the red and white muscles of the rabbit, tempt me to introduce a representation of these widely-differing curves procured by stimulating with a simple induced shock, and with a considerable variation of burden.

The interesting fact is observed, on stimulating the white muscle (fig. 11), that the greatest altitude is not obtained under

[1] *Archiv für Anatomie und Physiologie*, 1878.

the smallest burden (50 grms.) to which the tendon is subjected, for the elevation under 100 grms. is distinctly greater, whilst under 300 grms. the lever records as extensive an excursion as under the lightest weight. It is not till we burden the muscle with a weight of 500 grms. that the altitude is really impaired. That the lighter weights leave a certain number of muscle-bundles untensed and incapable of sharing, or of sharing to the full extent, in the elevation, is the explanation of this phenomenon. The state of such a muscle under a slight extending force is midway between the condition of "weighting" and "after-weighting" employed by physiologists in different forms of experimentation. Should a heavy weight be applied, that part of the muscle which was before supported and sheltered by neighbouring parts becomes extended, and stimulation occurring, the bundles contribute by their full contraction to the general

Fig. 12.
Soleus of rabbit (red muscle). Weighed with 50, 100, and 300 grms.
Maximal contraction.

shortening of the muscle. In the case of the white muscle of the rabbit, from which these curves were obtained, a weight of 50 grms. does not tense all the bundles, and it is not till 100 grms. is applied that they all become active to the greatest advantage. Kronecker[1] has observed, in the case of frog's muscle, that a weight, acting as a free burden, will be raised from a lower point to an absolutely higher point than is usually attained if the same weight be applied as an after burden.

The soleus, a thin muscle of red fibre (fig. 12), is considerably limited in its contraction by the addition of smaller weights; but as in the case of the white muscle, the original peculiarities of the curve are reproduced spite of the burdening to which the muscle is subjected. The typical form of both remains unaltered, and never admits of the two being confounded. Thus the

[1] *Arbeiten aus der Physiolog. Anstalt* zu Leipzig, 1871.

function of these muscles is as distinct as their structure. It is not improbable that variations in the nature of the course of contraction may occur within certain limits amongst the other white muscles of the rabbit, and also amongst the red—one red muscle differing somewhat from another in the form of its curve. A close study of such variations, and their comparison with peculiarities of structure and arrangement of bundles in individual muscles, would probably yield valuable information on the relationship which exists between the form of the muscle and its function.

Anatomical Notices.

HISTORICAL REFERENCES TO THE STRUCTURE OF NERVE FIBRES. By William Stirling, M.D., Sc.D., F.R.S.E., *Regius Professor of the Institutes of Medicine in the University of Aberdeen.*

Nearly all the text-books on physiology and histology state that medullated nerve fibres, when removed from the body, present a uniform or homogeneous appearance, but that within a short time they display a distinct double contour, due to the coagulation of the myeline or white substance of Schwann. It is further added, that the addition of water effects this change more rapidly. It was pointed out by Ranvier two years ago, that this statement is entirely erroneous, for he succeeded in seeing the double contour in a *living* nerve fibre while it was still within the body.

I have recently had occasion to satisfy myself of the correctness of this statement in connection with the nerves of the lungs of frogs and newts, where the nerves are easily seen in the living condition, by using Holmgren's apparatus for studying the circulation of the blood in the lung.[1]

Every one knows that Ranvier has the merit of discovering the existence of "nodes" in the medullated nerve fibres, and that between each two nodes, *i.e.*, in each interannular segment, a nucleus imbedded in a small quantity of protoplasm exists under the gray sheath or sheath of Schwann.

A few years ago, Kuhnt, Schmidt, and Lantermann discovered that the white substance of Schwann is in reality a very complex organ, that it is made up of "cylinder-cones" which fit one into the other by their bevelled edges, and that narrow oblique "incisures" separate the various cylinder cones from each other. Several cylinder cones lie in each interannular segment.

Ranvier showed that when a nerve fibre divides, the division always takes place at a node.

Now I wish to show that all these facts can be readily demonstrated in a *perfectly fresh nerve* fibre, nay, that as Ranvier has indicated, they may all be seen in a *living* nerve still within the body, as in the lung or tongue of a frog. It is indeed true, that when once a structure has been seen it is easy to see it again. These important facts in the histology of nerve fibres have only been made out after much laborious work, and with the use of many reagents.

There can be no doubt, however, that many of the older observers actually saw all or most of these details, but they failed to appreciate

[1] Fr. Holmgren, *Beiträge z. Anat. und Physiol.*, C. Ludwig, gewidmet 1874.

them. They began with the assumption that nerve fibres were homogeneous, and that the results they saw under the microscope were due to the effects of reagents on the nerve fibres.

I have recently looked through the older literature of this subject, and I think it will be easy to offer positive proof of these statements.

First, with regard to the "*Nodes of Ranvier*," let any one look at the figure copied from Kölliker, of a small branch of a muscular nerve of a frog in *Quain's Anatomy* (fig. 98), p. 146, 8th edition, and he will find a "node" figured quite distinctly. In the same figure he will find that the nerve fibre is represented as branching at these nodes or constrictions. I think this figure must bring the conviction to any unbiassed mind that the drawing is a faithful representation of what the observer actually saw, *i.e.*, the nodes,—but that he failed to interpret their real significance. In fig. 119 (p. 310) of Dalton's *Treatise on Physiology* (1859), a note of Ranvier is accurately figured, but it is described as a part of the nerve fibre where "the white substance of Schwann is nearly separated by accidental compression, but the axis-cylinder passes across the ruptured portion." The outline of the gray sheath passing from one segment of the nerve to the other is represented. The *nucleus* under the sheath of Schwann was also seen and figured by Dr R. B. Todd in his article on "Nerve," in fig. 335, *c*, in the *Cyclopædia of Anatomy and Physiology* (1839–47). A similar figure is given by Kölliker in the 5th edition of his *Handbuch der Gewebelehre* (1867).

With regard to the "*incisures*" of Schmidt and Lantermann, let any one glance at fig. 329 in the article by Dr. R. B. Todd on "Nerve," in the *Cyclopædia of Anatomy and Physiology* (Todd and Bowman, 1839–47), and he will find an accurate representation of the cylinder cones of Kuhnt and the incisures. The representation there given is in fact as good a representation of these structures as can be obtained by any of the most approved histological methods of the present day. This figure, one of the nerve fibres of an eel, is reproduced in Todd and Bowman's *Physiological Anatomy*, fig. 53, p. 210 (1856), where the appearances are again described as due to the action of water. It is to be noted, however, that Todd describes a nerve as homogeneous when it is first removed from the body, and therefore he assumes that the appearance which he so accurately and faithfully puts upon paper is due to the action of water. I think no one will doubt that he had before him these incisures; but that he imagined a nerve was homogeneous at first, and hence these appearances must be due to the action of the reagent which he added to the nerve fibres.

PECULIAR MALFORMATION OF BOTH FEET. By J. MACDONALD BROWN, M.B., *Demonstrator of Anatomy in the Owens College, Manchester.*

IN a subject laid on the table for dissection in the Anatomical Rooms of the Owens College, during the present session, a curious malformation of both feet was observed, of which the following are the brief notes.

The abnormality occurred in a woman about forty years of age. The body was fairly nourished, but beyond the condition to be described presented nothing remarkable for examination. The previous history and habits of the individual could not be ascertained. The cause of death was attributed to brain disease.

While the body was generally well proportioned, the leg was relatively longer than usual. The great peculiarity, however, consisted in the fact that the toes were awanting in both feet, although it is true a rudimentary "little" toe, possessing only one phalanx, was present on the right foot. This foot was also the longer of the two, and, from the disposition of the tarsal bones, appeared to be the broader. Yet their circumferences were identical, for what the left foot lacked in breadth, it made up for in depth.

Measurements made on the plantar aspect of both feet, from the posterior border of the calcaneum to the distal end of the second metatarsal bone, gave, in the case of the right foot, a distance of 6¼ inches, while in the left only 5¾ inches.

RIGHT FOOT.

Bones.—Tarsus normal. In the metatarsus, the bone of the hallux was much shorter than usual, and those of the other four were altered in their relative dimensions.

In the normal foot, it is worthy of remark that the third metatarsal projects most of all the five on the phalangeal aspect, then in order the second, fourth, and fifth bones; in the present case, however, the second metatarsal was the most projecting, then the third, fourth, and fifth, the distal extremities of these four bones forming a slight gradient from within outwards. Surmounting the fifth metatarsal was a single phalanx, which on examination proved to be an ungual one. The other bones possessed well-formed heads, which were coated with hyaline cartilage, just as in the normal foot. That of the hallux was somewhat irregular, and its plate of cartilage extremely thin.

Joints.—The intertarsal and tarso-metatarsal joints were all normal. The joint between the fifth metatarsal and the ungual phalanx already referred to, resembled an ordinary metatarso-phalangeal one as regards ligaments, synovial membrane, &c. Curiously enough, the heads of the

other four metatarsal bones were each invested by a perfect fibrous capsule, which was attached just behind the margin of the articular cartilage, and inclosed a well-defined serous sac.

Muscles.—The extensor muscles of the toes (brevis and longus), as also the extensor hallusis had the ordinary relations, but ended distinctly in the fibrous capsules referred to, and blended in their substance. That tendon of the long extensor going to the little toe was inserted into the base of the phalanx.

The flexor longus hallucis was inserted partly into the distal end of the first metatarsal, and partly into its fibrous capsule. The other muscles of the hallux (abductor, adductor, and flexor brevis) had the usual relations except that their insertions were attached to the distal extremity of the metatarsal bone, instead of to the base of a phalanx. The tendons of the flexor brevis digitorum did not as usual split to allow of the passage through them of those of the flexor longus, but the tendons of both muscles blended in the capsules, those of the flexor brevis being more superficial. With regard to the interossei, even these were not inserted into bone, but into the sides of the capsules, in positions corresponding to normal ones. The lumbricales blended with the extensor tendons at their insertions.

Left Foot.

Bones.—The tarsus seemed to be somewhat compressed laterally, with the result that its transverse diameter was less than that of the right foot.

Proximally all the metatarsal bones were normal, distally they had undergone strange modifications. Thus they were much shorter than the corresponding bones of the opposite foot, and terminated not in well-defined heads, but in stunted irregular extremities. The first and fifth stood out separately, while the remaining three lay more closely approximated to each other. One dense thick cartilaginous plate was common to the distal ends of these three bones, and this intimately attached to each served to bind them closely together. The tissue of which this plate was composed was found on microscopic examination to consist of hyaline cartilage which had undergone extensive fibrous degeneration. The head of the first metatarsal was irregular, and capped by a similar but thin cartilaginous layer, while on the pointed extremity of the fifth bone no such structure could be made out.

Joints.—Intertarsal and tarso-metatarsal joints normal. There was no metatarso-phalangeal joint, nor indeed could any arrangement of capsules or serous sacs be made out.

Muscles.—The extensor tendons to the first and fifth toes were inserted into the dorsal aspect of the distal extremities of their metatarsal bones; those to the second, third, and fourth, partly into the metatarsals and partly into the fibro-cartilaginous plate already referred to.

The flexor tendons (longus and brevis digitorum) were attached

as follows—the outer two to the fifth metatarsal, the others partly to the distal ends of the corresponding metatarsals, and partly to the cartilaginous plate covering them.

The tendons of the flexor longus hallucis was inserted into the dorsal aspect of the head of the metatarsal bone, and the attachments of the short hallucine muscles were similar to those in the right foot. A very large sesamoid bone was developed in relation to the flexor longus. All the interossei were inserted partly into the sides of the metatarsals and partly into the cartilage covering them, with the exception of the outermost plantar one, which was attached only to bone.

The lumbricales muscles were much as in the normal foot, ending in the blended extensor tendons. There was no trace of a transversus pedis muscle to be made out in either foot.

Over the ends of the metatarsals in both feet the skin seemed perfectly normal, and showed no cicatrices or thickenings, and, moreover, a considerable pad of fat intervened between it and the extremities of the bones.

The plantar fascia was but feebly developed, and more especially was this the case in the left foot.

The arteries and nerves had the usual distribution, but ended mostly in loops in the fat.

Having concluded my description, the following question naturally presents itself. What is the nature of the condition above detailed? Is it due to amputation, injury, or pathological changes, or is it the result of congenital malformation?

After careful consideration, it appears to me that we have here to deal with a case of congenital malformation of both feet.

Amputation or injury might have produced a somewhat similar condition. Had this been the case, in all probability cicatrices would have remained. Yet even if they had disappeared, the tissues along the line of amputation would to some extent have been matted together, and fibro-neuromata would have been present. The possibility of explaining the want of toes, &c. by intrauterine amputation is rendered improbable by the absence of all traces of a healing process.

Again, "dry" gangrene might have been the cause. That this was not the case seemed to be apparent from the soft and healthy condition of the parts, and from the absence of any discoloration or shrivelling of the skin.

After the above negative evidence in favour of malformation, let me state the positive.

With regard to the right foot, the presence of an ungual phalanx jointed on to a metatarsal bone is in favor of malformation. That the heads of the metatarsals were so well formed, and coated by cartilage, might point to the pre-existence of opposing surfaces of bone, but the fact that there were no traces of inflammatory processes or subsequent cicatrizations, as well as the perfect condition of the capsules, seemed to negative such a possibility.

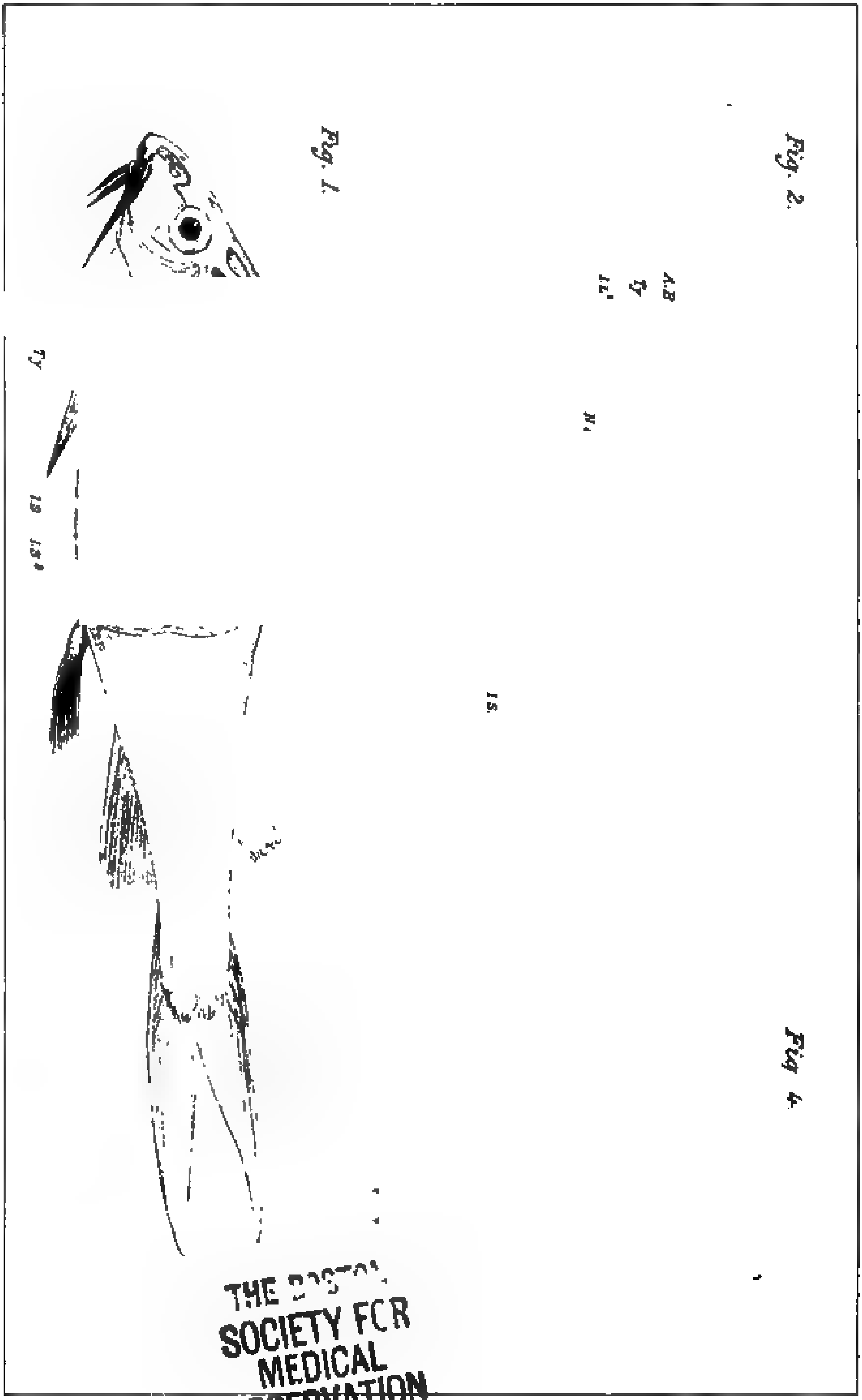
Whether the little serous sacs were synovial or bursal in character, may be a matter of debate. Possibly they were bursal, but too little is known of the development of joint-cavities to preclude the probability of their being synovial. Moreover, the relations they bore to the fibrous capsules favour the latter idea.

In the case of the left foot, the condition seems clearly to have been one of arrested development. This view is favoured by the relations of the cartilaginous elements to the bones, and also by the absence of cicatrices, or any indications of previous distinctive metamorphoses.

NOTE BY DR SHEPHERD ON HIS CASE OF CONGENITAL DISLOCATION OF THE HEAD OF THE FEMUR, IN VOL. XIV. p. 368.

With regard to the hip case, since I published the article I have found out the history. One of my students happened to be in the neighbourhood of the place where the woman once resided, and at my request made careful inquiries concerning her. He was fortunate enough to meet the midwife who officiated at her birth forty-five years ago. This midwife was nearly ninety years of age, and very talkative. It appears from her account that the birth was a *breech*, and that she had pulled down one of the legs, and had used considerable force, but without effect, and that the delivery had to be completed by the neighbouring doctor. The child did not walk till she was nearly four years of age, and always walked with a peculiar limping, jerky motion. On growing up she married, and was the mother of six children.

FRANCIS J. SHEPHERD.



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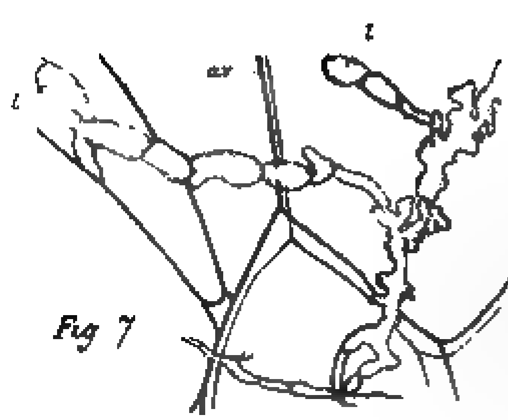

Fig 7

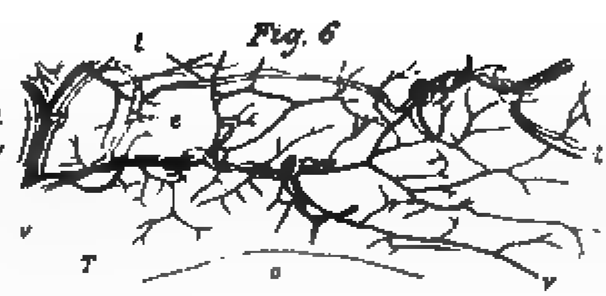

Fig. 6

Fig. 5.

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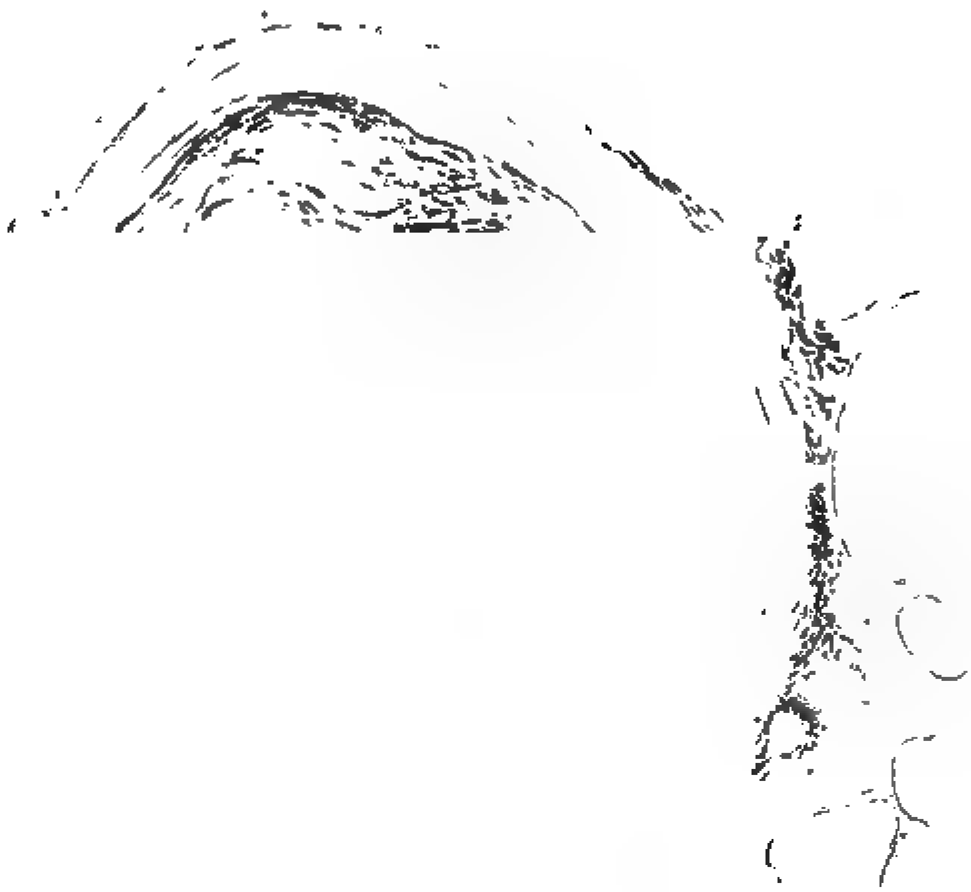
Fig 1



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Journal of Anatomy and Physiology.

THE OVARY IN INCIPIENT CYSTIC DISEASE. By VINCENT D. HARRIS, M.D., Lond., *Demonstrator of Physiology and late Casualty Physician, St Bartholomew's Hospital;* and ALBAN DORAN, F.R.C.S., *Surgeon to Out-Patients, Samaritan Free Hospital, Pathological Assistant to the Museum, Royal College of Surgeons of England.* (PLATE XXIII.)

WE, the authors of this paper, desire to take advantage of certain opportunities which we have enjoyed of studying incipient cystic disease of the ovary in its earlier stages. In the Samaritan Free Hospital the operation of ovariotomy is performed seventy to eighty times every year. In over one-eighth of the cases the operators, Dr Bantock and Mr Knowsley Thornton, find, that, after the removal of a large ovarian cyst, the opposite ovary presents such distinct symptoms of early cystic disease, that they remove it, knowing that otherwise a second operation will almost assuredly be necessary at no very distant date. A large number of such ovaries have been collected, and their appearances, when fresh, carefully described; the history of the patients, and notes as to the absence or regularity of the menstrual functions, together with records of abortion, parturition, or sterility, have also been preserved. The ovaries, within a few hours after removal, were placed within a half per cent. solution of chromic acid mixed with equal parts of methylated spirit. When sufficiently hardened, sections were prepared from them by means of Williams' freezing microtome. These sections were stained in logwood solution, and then mounted. Lastly, all have been since examined minutely by both of us, and separate notes carefully compared. The following observations are the result of this combination of study.

In the first place, we determined to divest ourselves of all preconceived opinions on the subject, before examining the sections; a task not so very difficult when it is remembered that previous theories neutralise each other by being so completely contradictory. Cystic disease of the ovary has been asserted to originate from the Graafian follicles, from the corpora lutea, from the ovarian stroma by a degenerative softening, from certain morbid, tubular, epithelial structures, and lastly from changes in the large blood-vessels in the tissue of the hilum. Most of the pathologists who trace the cysts to one of the above elements, admit the possibility of their origin from one or more of the others, a point on which we strongly insist. It would be tedious to quote all the authorities who hold each of these different opinions; they are named in most works on general pathology, but we shall have to refer to the researches of some of the more recent observers, in the course of the paper.

We have also been careful to select, for minute description, ovaries which were in all cases the fellows of others in an advanced stage of cystic disease; in all cases under 3 inches in diameter, but distinctly cystic; and in all cases showing more evidence of incipient symmetrical disease than the mere presence of simply over-distended Graafian follicles—evidence which many would consider to be valueless. We have examined cysts 4 or 5 inches in diameter, but the appearances in their stroma or cyst-walls might be due to secondary changes, and might give deceptive notions on the actual origin of the main and the smaller cysts. We have also examined ovaries apparently unaffected, in cases where their fellows have been the seat of large cystic tumours, and have noticed appearances very similar to other changes noted in ovaries more evidently morbid; these appearances will be described. In fact, we have chosen for description ovaries in as early, but at the same time, as evident a condition of cystic disease as could be procured, such specimens being most suited for the purpose. In all cases the disease in the opposite ovary has been the commonest multilocular form; dermoid cysts and tumours traced to a supposed parovarian origin have been put aside for the present. Yet these, unless it could be shown that all ovarian cysts spring either from a dermoid or a parovarian source, which is improbable,

prove that cysts in connection with the ovary may have more than one origin.

The first specimens worthy of attention are sections from the right ovary of R. C., aged 23, a single woman, from whom a large cystic tumour of the left ovary was removed by Dr Bantock in July 1880. The opposite ovary was distinctly enlarged and cystic, and therefore it was deemed advisable to remove it. The patient had menstruated regularly; the last period was ten days before operation, and there was no history of ovaritis nor dysmenorrhœa.

This ovary weighed three-quarters of an ounce. Its surface was, in parts, deeply puckered; the margins of the puckering were elevated and tubercular in parts. Close under the tunica albuginea was one large cyst containing a drachm of clear, pale yellow albuminous fluid; its cavity had a thick, highly vascular living membrane bearing perfectly flat endothelium, well displayed by nitrate of silver staining. Besides this cyst, numerous thin-walled cysts were laid open on cutting into the stroma; two contained fluid blood. No corpora lutea in any stage could be detected.

On examining the stained sections we found no changes in the germinal epithelium, which, as in most adult ovaries, was very indistinct. At the puckered depressions, the free surface of the ovary with its epithelium ran far, like a gulf or sea-loch, into the stroma, but did not bear the least resemblance to the cystic bodies presently to be described. This we noted, as at first we were reminded of Malassez and De Sinety's *enfoncements pathologiques.* Such structures may exist, and be the origin of cysts in ovaries where they are found, but here the depressions of the surface and the cystic bodies proved absolutely different in structure.

The stroma of the parenchyma consisted of the usual fusiform cells, rather closer together than in a normal ovary. The division of the "albuginea" or fibrous tissue beneath the germinal epithelium into an outer and inner longitudinal (fig. 1, *a* and *c*), and a middle circular layer (*b*) as recognised by Henle and Klein, was very distinct. The fibres of the middle layer, cut across, appeared as a series of round points, like nuclei, and caused this layer to look like a collection of epithelial cells,

traversed by longitudinal bands. These points, however, were very much smaller than the nuclei of certain epithelioid bodies admitted to exist in the ovarian stroma. The resemblance of transversely cut fibres to epithelium will be shown to be of great importance, when we come to consider the cysts.

Graafian follicles were entirely absent in the stroma, which was occupied throughout, from the hilum to immediately under the tunica albuginea, with large cavities bounded by very distinct and very thick walls (fig. 1, *d*). None of these cavities were absolutely spherical, some were triangular, others trapezoidal; the commonest form was like to the outline of a dumb-bell or an hour-glass. The cavities were, in some instances, filled with blood-corpuscles. At the first glance these cavities bear a strong resemblance to corpora lutea, an impression dispelled by careful examination. Under a $\frac{1}{4}$ inch objective a few small specks can be seen distributed over the middle of the thick coat of one of the cavities (fig. 1, *f*). On examining any part of the wall with an $\frac{1}{8}$ inch power, abundant, plain muscular fibres could be detected (fig. 2, *c*); mixed up with them are bodies (*b*) which at first appear to be epithelium, but on comparing them with the round points, above described, in the circular layer of the albuginea, they were found to be identical. In short, they are fibres cut across. Close to the cavity three or four groups of fibres, also cut across, were discovered (fig 1, *e*). These, too, at first gave a false impression, and reminded us of the vestigial epithelium found in normal ovaries. But we noted that the cells of such epithelium are much larger. To return to the examination of the wall of the cavity, its innermost or free margin showed a very distinct single layer of endothelium (fig. 2, *a*). The nature of the cavity at once became clear—it was a blood-vessel, with the transverse and circular muscular fibres of the middle coat and the endothelium of the tunica intima so distinct that, if the specimen had not been an ovary, no observer would have remained one moment in doubt about these appearances. We further examined the walls of arteries of the normal size in other parts of the same section, and also the vessels in preparations from healthy adult ovaries. In both, the walls were identical in nature, though inferior in thickness and development, to those of the cavities.

These cavities were still better seen in sections from a slightly enlarged ovary, fellow to a great multilocular tumour removed in June 1880 by Mr Spencer Wells. Their walls were not quite so thick as in the ovary from Dr Bantock's case, and a few very large cavities could be seen, the walls of which were even thinner, yet still bore traces of longitudinal and circular fibres. In short, this specimen threw a light on the fate of the enlarged vessels or arterioles, as, strictly speaking, we must call them; they were destined to dilate, to become obstructed in parts, and to develop into cystic cavities between the points of obstruction. Plugging of the narrower cavities we found to be very frequent. In this ovary the entire surface was deeply puckered, but none of the depressions of the tunica albuginea, not even those that ran one-eighth of an inch into the stroma, showed any signs of becoming cystic by closure at the surface and dilatation deeper down; nor could any morbid process of cell-proliferation be traced from the epithelium lining the deepest processes of the albuginea towards the stroma, which was perfectly healthy around these depressions. Lastly, there was neither resemblance nor communication between the depressions of the tunic and the cavities formed by dilated vessels.

We examined many more ovaries, but found totally different appearances in several that were as surely in a state of incipient cystic disease as the two already described, and, like them, had been removed from patients in whom the opposite ovaries had become large multilocular cysts. Whilst those already discussed showed morbid appearances mostly in their vessels, these gave evidence of abnormal changes commencing in the Graafian follicles, or rather in what were follicles. We say this, because in no case could we trace disease from simple distension of a normal follicle, with changes in its wall, nor even from the corpora lutea of pregnancy and menstruation. Disease, in all cases, appeared to have started from the follicles that had undergone involution without ever having taken part in the active processes for which they are functionally destined; but of the myriads of follicles that exist in an infant's ovary, the greater proportion are, of necessity, bound to degenerate in this manner.

Dalton,[1] Beigel,[2] Slavjansky,[3] and others, have minutely described these degenerate follicles.

On July 15, 1880, Dr Bantock removed a large multilocular cyst of the right ovary from a robust young married woman, aged 28, whom we will briefly term "Case 2." She had been married nearly two years, and not having menstruated for several months, was believed to be pregnant. The left ovary was clearly in a state of incipient cystic degeneration, and was therefore removed. It measured 2¾ inches in its long diameter, and weighed 360 grains. Examined fresh, the surface was but little puckered; on section it appeared full of thin-walled cysts containing highly albuminous fluid. These cysts were simply Graafian follicles bearing perfect ova. Between these follicles the stroma was abundant, pale, and succulent.

On microscopic examination no morbid changes could be detected in the tunica albuginea. The stroma consisted of the normal spindle-shaped cells, not closely packed, but freely distributed as in a healthy child's or young girl's ovary. This we noted to counteract any hasty conclusions that cirrhotic changes in the stroma may prevent the follicles from bursting, and allow them to slowly develop into large cysts. There were plenty of cysts but no cirrhosis. In fact, the loose stroma was over-abundant, and bore large numbers of degenerate follicles (by this term we imply such as have never taken a share in pregnancy nor menstruation). Some were reduced to a mere cloudy sinuous band, no longer forming a complete chain; the tissue partly included by this band was looser than elsewhere, yet not undergoing any kind of degeneration. Most of these follicles formed fusiform bodies composed of radiating cloudy tubes, or rather bands, bearing traces of degenerate nuclei. In the centre were broken-down masses of pigment. The tubes were, externally, very sharply bordered by the surrounding stroma, which, however, sent in filiform processes of elongated and nucleated cells (see fig. 3).

[1] "Report on the Corpus Luteum," *Trans. Amer. Gynecological Soc.* vol. ii. 1877.

[2] "Zur Naturgeschichte des Corpus Luteum," *Archiv. f. Gynækologie*, vol. xiii. 1878.

[3] "Zur normalen und Pathologischen Histologie des Graaf'schen Bläschens des Menschen," Virchow's *Archiv.* vol. li. 1870.

We will pass, without comment, to another case of suspected symmetrical disease. On June 1, 1880, Dr Bantock removed a multilocular cyst of the left ovary from a single woman, aged 25, who had menstruated regularly until operation. In this third case the right ovary was enlarged and distinctly in a state of incipient cystic degeneration, its surface was covered with flakes of lymph, probably the result of tapping, performed a few weeks previously, to relieve the great distension of the opposite cystic ovary. The patient never appeared to be subject to any form of dysmenorrhœa.

This ovary weighed over half an ounce; its surface, when freed from the inflammatory deposit, appeared in general smooth, but presented a few puckered depressions. The interior contained follicles from $\frac{1}{20}$ to nearly $\frac{1}{4}$ inch diameter, but no corpora lutea of menstruation; ova were found in the fluid of most of the distended follicles. On section, for the microscope, the stroma appeared perfectly normal; the large spindle-cells were arranged in all directions, and lay at wide intervals from each other. The germinal epithelium of the tunica albuginea was normal, and no morbid involutions of the cells into the stroma could be detected. The distended follicles showed no morbid changes. But opaque bodies, some $\frac{1}{10}$ inch in diameter, lay in the stroma. On close examination, these bodies proved to show a morbid form of involution of follicles that had never been ruptured, as in the last described specimen, only here the differentiation from normal involution was more advanced.

In fig. 4, the appearance of the largest of these bodies is sketched, as seen under a 2-inch power. The stroma is condensed to a slight extent around the body, and sends numerous delicate ingrowths between the opaque, tube-like masses of which the body is essentially made up. These masses differ in no way, except in arrangement and in their increased development, instead of effacement, from the altered epithelium of an unburst follicle in cases of normal involution. In fig. 5, a portion of the centre of the body is shown as seen under a $\frac{1}{4}$-inch objective. This higher power demonstrates what cannot be seen under a lower object glass, and this is the fact that the ingrowths from the stroma are not lost in the midst of the opaque masses, not ending as little flaps or pennons, but on the

contrary, form a wide and complete meshwork, enclosing spaces. Let it be remembered that it is a section and not a solid that is being inspected, and then we must conclude that the spaces enclosed by a border of spindle cells, continuous with the stroma of the ovary, are really cavities, and there is no reason to doubt that most of these cavities are more or less completely closed, or at least, can become so. In fact, we seem to see a very evident method of cyst-formation, and, what is more, this formation is multilocular from its very origin. The tube-like bodies cut off as loops in these spaces or cavities, being mucoid in appearance, would account for the mucoid contents always observed in the smallest cysts that can be found among the immense cystic cavities of a large tumour of the ovary, as in the fellow to this specimen. Such cysts may lie alongside of true Graafian follicles, which may exceed them in size, and be clearly in a state of true evolution or normal involution. In the denser strands of stromal ingrowth, in this specimen, large vessels can be detected. These cannot but indicate free nutrition of the morbid structure, a nutrition which must maintain and develop the entire abnormal fabric to an indefinite extent, which is the case, if, as the authors of this paper believe, these bodies now under consideration represent one of the origins of multilocular ovarian cysts.

In all the slightly enlarged ovaries removed, since the above described specimens were examined, from cases of cystic disease of the opposite ovary, we have found one of the two appearances already discussed—namely, an abnormal condition of certain vessels in the stroma, or else some differentiation in the involution of unruptured follicles. The first case showed the vascular change, the third demonstrated the follicular changes to perfection; the second was a less active form of the same kind of degeneration, the mucoid degeneration of the follicles being associated with less abundant and less active ingrowths from the stroma. In one ovary, 2 inches long, 1 ounce in weight, and fellow to a large multilocular cyst removed from a woman, aged 29, by Dr Bantock, a similar, yet not identical, method of cyst-formation from unruptured follicles could be distinguished. In this ovary was one corpus luteum representing very recent menstruation, its surface showing a small aperture whence blood leaked during removal, at the operation. Some true

normal follicles lay in the stroma of this fourth case (fig. 6, *a*), but deeper in the ovarian tissue lay bodies from $\frac{1}{10}$ to $\frac{1}{8}$ of an inch in diameter, appearing to the naked eye like mucoid masses. Under a pocket-lens they assumed the appearance shown in fig. 6, *b* and *c*, being cavities with boundaries not uniformly distinct, and with transparent, hazy contents, broken-down in the middle either from actual degeneration, or in the process of preparation. Under a No. 8 Hartnack objective the hazy contents appeared to consist of large branched cells (fig. 7), the processes from each cell freely uniting with others from neighbouring cells. In fact, we have here a myxomatous change. At the border of each of these morbid bodies a strong objective showed the close relation between the branched cells and the surrounding stroma (fig. 8). The processes of the cells joined certain fine fibres in the stroma. Besides, the stroma itself sent ingrowths among the branched cells, and here again the same relation between the stroma and the processes of the cells could be seen; indeed the sketch (fig 8) is actually from such an ingrowth. In the midst of the ingrowths some faint traees of branched cells were visible. This would lead us to suspect that the myxomatous changes arose from the ingrowths, the branched cells either springing from them, or developing and perishing with them. This is, in fact, more probable than that such changes should begin in the practically dead or degenerate, hazy, tube-like tissue which represents the relics of the membrana propria of a follicle in unruptured follicles undergoing normal involution.

Such are the appearances which we have observed in ovaries, all the fellows of large multilocular cysts, and all so distinctly enlarged and so abnormal in appearance as to afford the strongest presumptive evidence that they were in a state of incipient cystic degeneration. We have rejected all cases where we believed that simple congestion of the ovary, due to recent menstruation, explained some slight enlargement, as well as all ovaries with marked cirrhosis of the stroma; and, mindful of the researches of Dalton, Beigel, Slavjansky, Patenko, and earlier authorities, we have been careful to watch the process of normal involution of follicles after menstruation and impregnation, so as not to confound natural with morbid appearances. We strongly

insist on the great necessity of gaining an accurate knowledge of the nature of every normal change in the follicle, as seen under the microscope, including, above all things, the natural involution of unruptured Graafian follicles. Equally important is it that the student of ovarian pathology should thoroughly distinguish dilated vessels from cysts, and not confound a bundle of the spindle-shaped cells of the stroma or of the circular coat of the vessels, when cut transversely, for a collection of round cells with distinct central nuclei. To gain an accurate knowledge of the corpus luteum and the changes in the follicles, requires much time and experience. To make the mistake about transversely cut fibres is more easy that one would at first suppose.

The numerous theses, monographs, and shorter papers on the true origin of ovarian cysts, that have appeared within the last few years, are too well known for even brief quotation. Roughly speaking, we have the Graafian-follicle dilatation theory, the colloid degeneration of stroma theory, the dilated vessel theory, and the special tube theory. We think it more advisable to summarise our own conclusions than to quote other researches at length.

1. There is strong evidence that multilocular cystic disease of the ovary may arise from two totally different ovarian elements.

2. Cysts may arise from partial dilatation and partial obstruction of enlarged and thickened blood-vessels, as Noeggerath maintains,[1] and we think, as he does, that many errors have arisen from imperfect knowledge of the appearance of blood-vessels in the ovarian stroma.

3. Cysts more frequently appear to originate in changes in those Graafian follicles that undergo involution without having ever ruptured; this includes a large majority of the follicles, when we remember the vast number found in the ovary at birth, and bear in mind that involution of many follicles takes place between birth and puberty.

4. The morbid changes which replace normal involution of the follicle are an active ingrowth from the stroma, and a long persistence of the cloudy tube-like bodies that represent the remains of the membrana propria of the follicle. These two

[1] "The Diseases of Blood-Vessels of the Ovary in relation to the Genesis of Ovarian Cysts."—*Amer. Journ. of Obstetrics, &c.*, vol. xiii., 1880.

processes sometimes proceed at an equal rate, sometimes irregularly.

5. When the relics of the membrana propria are slow to disappear, and the stroma slowly sends ingrowths amongst these relics, we find the cystic bodies described as seen in the fourth case, containing myxoma-cells partly, at least, connected with the ingrowths. Such delicate tissue, made up of these cells, must soon break down as the cyst becomes larger.

6. When the process of ingrowth of stroma into the follicle, during involution, is particularly active, the ingrowths interlace and rapidly form cystic spaces, including portions of the cloudy relics of the membrana propria, giving the appearances seen in the third case.

7. On the other hand the stroma may show little or no tendency to develop ingrowths, but the relics of the membrana propria may break down very slowly, and end, not in simple effacement and incorporation with the stroma, but in slowly breaking down, as in the second case. This must necessarily end in the formation of a cyst full of a colloid or semi-fluid material, the completely broken down granulosa, &c.,; previous theories on colloid degeneration of the stroma itself may be based on the overlooking of the intra-follicular origin of the colloid collections. In all cases of myxomatous or colloid changes, or simple rarefaction of tissue, we found full evidence that those changes were in degenerate follicles and never free in the stroma.

8. All these changes in the degenerating membrana propria and the tissue surrounding the follicle, begin as exaggerations of the normal process of involution, which is never a mere disintegration and degeneration of the follicle. Slavjansky, in the work we have quoted, gives accurate drawings of the normal process. Patenko traces these abnormal changes to sclerosis of the follicle-wall, under different conditions.[1]

9. These changes in the follicle do not appear due to inflammation; indeed, in old inflamed ovaries the atrophy of the follicles appears to be quicker and more complete than in healthy ovaries, so that no trace of them is left, excepting certain granular masses.

[1] In Virchow's *Archiv.*, May 1881, he demonstrates the manner in which this process ends in the formation, not of cysts, but "corpora fibrosa."

10. The manner in which the young cyst first becomes invested with its characteristic epithelium is obscure. We found that the "germinal epithelium" of the tunica albuginea and the cells of the granulosa of normal follicles never invaded the ovarian stroma, and the epithelial relics of the Wolffian tubes, that are usually found loose about the stroma, were never in close relation to any of the bodies we have described. In the case of the dilated vessels, the endothelium must be the most natural starting-point of the epithelial lining of cysts derived from such vessels. Remembering the changes in the mucous membrane of a prolapsed vagina, the endothelium may, we can conceive, alter its character when the nature of the free space on which it borders has become completely altered. Should the theory of Cripps[1] be even partly correct, that nuclei in lymphoid or connective tissue may gather protoplasm around them till they form real epithelioid bodies lining spaces deeply situated in solid structures, we could readily account for the origin of the epithelial lining of any cyst. We do not profess to accept as positive that observer's theory, that the nuclei in the sub-mucous tissue of the rectum are normally the parents of the columnar epithelium of the mucous membrane, although microscopical evidence tends to support it; his other opinion, expressed above, that such nuclei may become epithelioid, is far more probable. An area in any tissue, with such nuclei, breaks down—the nuclei bordering on the broken-down region must be placed at once in different circumstances to their normal state, deep in tissue and away from any free surface. We do not find such nuclei on free surfaces; we do find epithelium. In other words we see no difficulty in supposing that the epithelial lining of ovarian cysts is probably developed from nuclear elements in the bodies above described. It seems, on mere reasoning, less far-fetched to assert that this epithelial lining is derived from pre-existing epithelium. To this we reply that, on actual observation, detecting incipient cystic cavities and also healthy epithelium on the tunica albuginea, in the follicles, and, as embryonic relics in the stroma, often in one single section, we find no connection between the cavities and any of these three normal epithelial elements. We must not conclude that

[1] *Cancer of the Rectum.* See particularly Pl. III. fig. 1, in that work.

when the mucoid contents of the imperfectly involved follicles have broken down to their utmost, the cellular elements immediately adjacent to the resulting semi-fluid material, simply assume the epithelial type. Only as long as the source whence normal epithelium is renewed remains obscure, so long must this question remain unsettled.

INCIPIENT CYSTIC DISEASE OF THE OVARY.

(Plate XXIII.)

From Drawings by A. Doran.

Fig. 1. Section of the smaller ovary of Case 1 (R. C., aged 23) × 40:—*a* and *c*, outer and inner longitudinal layers of the albuginea; *b*, the middle layer, with the circular fibres cut across transversely—the fibres are arranged in bundles intersected by fibres running in a different direction; *d*, a large, thick-walled vessel, its lumen is partly filled with corpuscles; *e*, fibres of the deeper part of the ovarian stroma, cut transversely, as in *b*; *f*, circular fibres of *d*. No trace remains of the normal follicular structure of the ovary.

Fig. 2. A segment of the wall of the vessel *d*, fig. 1, × 400:—*a*, endothelium; *b*, circular fibres of the muscular coat, cut transversely; *c*, longitudinal fibres; *d*, a few fibres (strictly, elongated cells) of the stroma, some cut transversely.

Fig. 3. A section of the smaller ovary of Case 2, as seen under a 2-inch objective. It shows a very large degenerate follicle presenting appearances but slightly different from the normal condition, but the ingrowths from the surrounding stroma and the breaking down of the central portion are made distinct. The stroma abounded with these bodies, as well as with normally degenerating follicles.

Fig. 4. One of the bodies from the ovary of Case 3 (2-inch objective). It differs considerably from fig. 3, the ingrowths of the stroma are very active.

Fig. 5. The central portion of the same body, × 210. The stromal ingrowths here may be seen to have penetrated very completely, forming spaces—which in the actual solid condition of the part would be cystic cavities—cutting off and enclosing some of the original substance of the body, which is a follicle undergoing abnormal changes in its involution. A portion of a small vessel lies in the stromal ingrowth, to the left.

Fig. 6. Portion of the ovary from Case 4, as seen under a pocket-lens:—*a*, a normal follicle; *b*, *c*, follicles in an abnormal state of involution, they contain a transparent material, partly broken down in the centre.

Fig. 7. A part of this material from *b*, fig. 6, × 400; it consists of cells of the variety observed in myxomata.

Fig. 8. A stromal ingrowth into *b*, fig. 6, × 400; its fibres are connected with *a*, branched cells composing the material shown in fig. 7.

ANATOMY OF THE KOALA (*Phascolarctos Cinereus*).

By A. H. YOUNG, M.B., F.R.C.S., *late Assistant-Lecturer on Anatomy, The Owens College, Manchester.*

IN a former communication to this *Journal*[1] I directed attention to the genito-urinary organs of the Koala, in so far as these related to the male.

The principal features of anatomical interest which more especially refer to the remaining visceral arrangements are already more or less well known, mainly through an excellent description of them which was read by Mr Martin[2] in 1836, before the Zoological Society of London.

Nevertheless, I found, when engaged in the dissection of three well-preserved specimens of *Phascolarctos*, that there were still some few points which, so far as I have been able to ascertain, seem to have been overlooked hitherto. These it appeared advisable to record, whilst at the same time I am enabled in many respects to confirm the observations of Mr Martin.

Mouth.—The lips are well developed—a slight vertical cleft marks the upper one. The muzzle is smooth, but covered with fine downy hairs. As in marsupials generally, the mucous membrane of the hard palate is marked by a series of well-defined transverse ridges. Eight in number, the ridges are most strongly marked anteriorly; those posteriorly situated present a finely serrated free margin. The soft palate is remarkably long. It extends backwards for a distance of 3½ inches,[3] and reaches as far as the thyroid cartilage; on its upper surface the mucous membrane is raised into a longitudinal mesial ridge. There is no *uvula*; on the contrary, the posterior margin of the soft palate presents a deep cleft in the middle line, into which the projecting larynx may be received, and thus a direct passage between the upper aperture of the larynx and the nasal chambers be more or less shut off from that of the mouth and pharynx.[4] This arrangement, by means of which the larynx of the fœtus is

[1] On the Male Generative Organs of the Koala, *Journ. of Anat. and Phys.*, vol. xiii. p. 305.

[2] Notes on the Anatomy of the Koala, *Proc. Zool. Soc.*, 1836.

[3] This, and the succeeding measurements are taken from the smallest of the specimens examined, the total length of which is 20½ inches.

[4] Art. "Marsupialia," *Todd's Cyclopædia*, vol. iii. p. 326.

guarded during the passage of milk down to the stomach, is not however so complete in the Koala as in the Kangaroo. The inner surface of each cheek presents a well-marked buccal pouch. This extends in the direction of the eye, and lies between the cheek and upper jaw, its opening into the mouth being wide and elongated. The anterior margin of the pouch is on a level with the canine tooth, and is formed by a fold of mucous membrane which passes to the intermaxillary bone; the posterior margin, which is opposite the hinder border of the premolar, is formed by a fold of mucous membrane which separates the pouch from the cavity of the cheek. Immediately behind the buccal pouch, and at a point corresponding to the interval, between the two anterior molars, is the opening of the parotid duct.

Salivary Glands.—Of the salivary glands, the parotid is exceedingly large. In the neck there are numerous small isolated and detached portions. There is a well-marked sub-maxillary gland, but I was not able to distinguish a separate sublingual. A small gland, sub-zygomatic in position, rested upon the buccinator.

Tongue.—The tongue is very similar to that of the Kangaroo. Posteriorly it is thick, but anteriorly it becomes thinner, and assumes a spatulate character. The base is constricted, and the posterior extremity appears prominent and projects backwards into the pharynx. Small filiform papillæ of a simple character cover the greater part of the dorsal surface and margins; interspersed among these are numerous fungiform papillæ of a whitish colour. These are most plentifully distributed along the free margins and tip of the organ. A single isolated circumvallate papilla is situated mesially half an inch in front of the posterior projecting margin of the tongue.

Professor Owen[1] describes also "a single large fossulate papilla" in the Kangaroo. In the single specimen of this animal, however, which I have had an opportunity of examining, I found three such papilla arranged as in dendorlagus, &c.

Teeth.—Dental formula—

$$i\,\frac{3-3}{1-1}\quad c\,\frac{1-1}{0-0}\quad p.m.\,\frac{1-1}{1-1}\quad m\,\frac{4-4}{4-4}\quad \text{total, } 30$$

[1] *Anat. of Vert.*, vol. iii. p. 191.

Of the upper incisors the posterior one on each side is small. The upper canine also is small; it is situated just behind the premaxillary suture, and occupies an isolated position in the space between the incisor teeth and the premolar. There is a similar interval between the lower incisor and premolar. These spaces in the Koala are never occupied by functionless free molars, such as exist in the Phalangers.[1] The molars are quadrituberculate. In certain respects, therefore, the dental formula of the Koala differs from that of the Wombat, and approaches rather to the Kangaroo. From the Kangaroo the Koala differs in the presence of canines in the upper jaw, and from the Wombat in this and also in the presence of posterior incisors in the same jaw. In its dentition the Koala agrees very closely with the Phalangers, differing from them only in the absence of a few inconstant and functionless premolars which exist in *Phalangistidæ*. For this reason Latreille assigns to Koala a position next to the Phalangers.[2]

Pharynx is tubular; its calibre but slightly exceeds that of the œsophagus, with which it becomes continuous. From the root of the tongue to the cricoid cartilage it measures between 3 and 4 inches, and for almost its whole extent it is divided into an upper and a lower channel by the greatly elongated soft palate.

The œsophagus extends from the pharynx, and, passing between the muscular fibres derived from the crura of the diaphragm, terminates immediately after it enters the abdomen, at the lesser curvature of the stomach, about 1 inch from its cardiac end.

Stomach is simple in character; in none of my specimens did it present the contraction described by Martin[3] as dividing it into two parts. This viscus is of an elongated ovoid form, narrowing slightly towards its pyloric extremity. Its surfaces are directed forwards and backwards, and its curvatures upwards and downwards (*i.e.*, dorsad and ventrad) respectively. A well-marked thickening of the coats of the stomach, together with a constriction, indicates the position of the pylorus.

[1] Owen, *Anat. of Vert.*, vol. iii. p. 291.
[2] Owen "On the Dentition of the Koala," *Proc. Zool. Soc.*, 1838, p. 154.
[3] *Proc. Zool. Soc.*, 1836, p. 110.

The mucous membrane is smooth, with the exception of that portion which occupies the cardiac end of the stomach; this is thrown into longitudinal rugæ. As in the Wombat[1] (and Beaver), a large conglomerate gastric gland exists. It is situated, as in these animals, on the smaller curvature of the stomach, close to the œsophageal opening. The glandular patch is somewhat circular in form, and presents numerous large oval apertures, at the bottom of which are smaller depressions irregularly disposed.

Small Intestine—measures 8 feet in length, the duodenum is slightly dilated at its commencement, the remainder of the gut is of uniform calibre; when flattened it measures half an inch across. The mucous membrane is smooth throughout. The circular muscular fibres of the walls are strong, and arranged in bundles, which give a transversely striated appearance to the walls of this part of the alimentary canal.

Large Intestine and Cæcum.—On opening the cavity of the abdomen the great intestine, with its cæcal appendage, entirely concealed such abdominal viscera as were situated posterior to the stomach. Martin describes rightly the cæcum as turning spirally on itself.[2]

The large intestine itself, from the cæcal orifice to anus, measures 9 feet 10 inches; its diameter at its commencement and for 3 feet onwards is 2½ inches, but thereafter it dwindles to the size of the small intestine, and so remains to its termination.

Cæcum is of enormous length, being indeed more than three times the total length of the animal itself, and more than half the length of the great intestine.

In the specimen, from which all dimensional data are taken, the cæcum measures 5 feet 3 inches (the specimen itself, as noted before, being 1 foot 8½ inches from snout to end of rudimentary tail), whilst in another of the koalas, which itself measures 2 feet 2½ inches, the length of the cæcum is 7 feet.

At its commencement the diameter of the cæcum equals that of the broadest part of the great intestine; from this there is a gradual and progressive diminution down to a somewhat bluntly

[1] Home, *Phil. Trans.* Lond. 1808, p. 312, plate ix.

[2] *Loc. cit.* p. 111.

pointed extremity. The whole of the cæcum, together with the upper part of the colon, is regularly sacculated.

The mucous membrane of the large intestine and cæcum is disposed in parallel longitudinal laminæ, some of which measure half an inch in depth; they project into the interior, and their arrangement is well seen in a transverse section of the gut.

This longitudinal lamination of the mucous membrane disappears in the narrow part of the great intestine, but reappears in the rectum, which is longitudinally corrugated. Ileo-cæcal orifice is circular and prominent; from its circumference laminæ of the mucous membrane radiate, most of which become continuous with the longitudinal laminæ just described. Upon each side of the ileo-cæcal valve an irregular, somewhat circular, glandular patch, in the centre of which are numerous glandular sacculi of large size, is situated.

Abdominal Glands.

Liver.—The liver presents the maximum marsupial tendency to subdivision into numerous lobes. According to Owen, no less than thirty to forty of these latter may be distinguished.

Following the method of description adopted by Professor Flower,[1] the liver of Koala consists of right and left segments, the division being well marked by the attachment of the suspensory ligament, which indicates the position of the umbilical fissure. The left segment is divided into lateral and central lobes by the left lateral fissure; and a corresponding division into lateral and central lobes, by means of a lateral fissure, exists also on the right side.

A deep fissure for the gall bladder divides the right central lobe into almost equal parts. There is a well-defined Spigelian, as well as a caudate lobe. Both right and left segments present fissured margins, and on the right side numerous secondary lobes are thus differentiated.

The gall bladder measures 3 inches in length, and its fundus projects considerably beyond the ventral margin of the liver. Its general form is ovate rather than pyramidal, the base being the broadest and the fundus the narrowest part. The duct of the gall bladder unites with the hepatic duct close to the liver,

[1] *Med. Times and Gazette*, vol. i. 1872, p. 293.

and the resulting duct, after receiving that of the pancreas, opens into the duodenum 2 inches below the pylorus.

The internal surface of the gall bladder is quite smooth.

Pancreas measures 4½ inches in length, and, as in other marsupials, is enlarged at its splenic extremity; gradually narrowing, it reaches to the duodenum, and by a small duct opens into the "ductus communis."

Spleen consists of two parts, united by an isthmus. One portion, the larger, is broad and of an irregular quadrilateral form; the other is small and tongue-like. The total length is 3 inches.

Genito-Urinary Organs.

Those in the male[1] have already been described at some length in a previous communication. Of the three specimens which came into my possession, one was a female; but, unfortunately, it had been somewhat injured in the region of the pelvis and lower part of the abdomen, so that I am not able to speak with certainty as to the anatomy of its pelvic viscera. So far as I could ascertain, however, the principal features appear to be as follows:—Kidneys, ureters, and bladder, are just as in the male. Uro-genital canal measures 2 inches in length; its mucous membrane is thrown into longitudinal rugæ. The external orifice of this canal is enclosed, along with that of the rectum, in a common sphincter cloacæ.

Generative System.

Ovaries.—Each ovary is oval and sub-compressed. It equals in size, and somewhat resembles, in outline, a French bean; its surface is slightly lobulated. Each is contained in a well-marked pavilion furnished by the broad ligament.

The Fallopian tubes are slender, and somewhat spirally arranged; not nearly to such a marked extent, however, as Owen figures in *Didelphys dorsigera.* Each Fallopian tube opens into its corresponding uterus.

Each uterus measures 2 inches from fundus to os tincæ. The lining membrane is soft; smooth and velvety near the fundus, it becomes arranged in longitudinal rugæ inferiorly. The

[1] *Journ. of Anat. and Phys.* vol. xiii. p. 305.

rugæ converge towards the os, and the margins of the latter have in consequence a slightly serrated appearance.

The walls of the uteri become thicker near the ora uteri, which are distinct and well marked.

Vaginæ.—Traced from its opening into the uro-genital canal, he vagina of each side ascends upwards and slightly outwards, then expanding receives the orifice of the corresponding uterus, and next descends united to its fellow of the opposite side to form a central "cul-de-sac," which descends towards the uro-genital canal, but does not communicate with it.

The culs-de-sac of opposite sides are united by their mesial walls, and these blended together form a septum between the two. In Koala, as in the Phalangers, Kangaroos, and Wombat,[1] the septum is imperfect above, and so permits a communication between the vagina of opposite sides. The septum also presents a small oval opening a little distance lower down. In the *Dasyurus viverrinus* and in *Didelphys Virginiana*, the septum dividing the mesial culs-de-sac is complete, and the two walls can be separated from each other,[2] whilst in *Didelphys dorsigera* the vaginæ are still more distinct from each other.

The partial union of the opposite vaginæ in Koala, Phalangers, &c., is somewhat interesting, as it apparently indicates a tendency to the complete coalescence of the Müllerian ducts to form the single vagina of the placental mammal.

In the Koala each vagina proper is about one-half the diameter of the uterus. Its mucous membrane, in common with that of the cul-de-sac, is smooth, but it becomes rugose near its inferior termination. The uro-genital canal has already been referred to.

Two muscles, corresponding exactly to the retractores penis in the male,[2] spring from the sacrum, and terminate upon each side of the urethro-sexual canal, near its external orifice.

Sphincter cloacæ encloses both the anus and uro-genital orifice. Anteriorly a few fibres are attached to the symphysis pubis.

Mammary glands are two in number. I was only able to distinguish a single nipple to each gland.

A well-defined compressor of the mammary gland (*ilio-marsupialis—Cuvier*) springs from the ilium, winds round the

[1] Owen, art. "Marsupialia," *Todd's Cyclop.* vol. iii. p. 316.

[2] *Journ. of Anat. and Phys.* vol. xiii. p. 312.

marsupial bone, and expanding passes to the mammary gland beneath the pouch.

Professor Owen[1] considers that the chief function of the marsupial bone is to add the power of the pulley to the compressor of the mammary gland, and to effect the requisite change in the course of the contractile fibres of the muscle.

In the conformation and arrangement of the generative organs the female Koala is typically marsupial in character. Relatively large, the ovaries are not quite so smooth as those of the Kangaroo, whilst they contrast strongly with the botryoidal form and large size of the ovaries of the Wombat. But it is in respect of the vaginal portions of the female generative organs that the greatest variations take place; the extent to which these are observable in the various marsupial genera differs materially.

In the possession of two true vaginæ, the Koala agrees with all other marsupials; in the further complication of these vaginæ by mesial culs-de-sac it agrees with most, the *Didelphys dorsigera*[2] forming an exception to this rule.

Inasmuch as in Koala the mesial culs-de-sac communicate with each other through an imperfect septum, it is allied to the Phalangers and Kangaroos, but differs from the Opossums, Dasyurus, and probably also from the Wombat.[4]

In the comparative shortness and straight character of the true vaginæ, and the relatively larger development of the mesial culs-de-sac, the female organs of Koala approach somewhat to the condition met with in the Kangaroo Rat[5] (*Hypsiprymnus murinus*).

Comparing the visceral anatomy of Koala with that of other marsupials, it is at once seen that, although in its dentitional characters it closely resembles the Kangaroos, yet it contrasts strongly with these latter in the possession of a simply arranged stomach, which is provided with a special glandular apparatus. The cæcum of the Koala also exceeds in size that of the Kangaroo,

[1] *Anat. of Vert.* vol. iii. p. 769.

[2] *Todd's Cyclop.* art. "Marsupalia," vol. iii. p. 313, fig. 137.

[3] *Cyclop.* 316.

[4] *Todd's Cyclop.* vol. iii. p. 316, art. "Marsupialia." See also "Notes on Anatomy of the Wombat," *Proc. Zool. Soc. Lond.* 1836, p. 52.

[5] Owen, *Anat. of Vert.* vol. iii. p. 683.

which, however, is characterised "with all the Poephagans" by the possession of a long cæcum.

A simple stomach, uncomplicated with sacculi, exists amongst sarcophagous, entomophagous, and carpophagous marsupials. In this respect koala agrees with them, rather than with the poephagans; but inasmuch as its stomach is provided with a conglomerate glandular apparatus, it differs from them, and resembles the rhizophagous (Wombat), in which the stomach is almost identical.

The very long cæcum possessed by Koala is also a characterising feature in the allied Phalangers. Shorter, but still elongated, are the cæca of the entomophagous and poephagous tribes; very short is the cæcum in rhizophagous (Wombat), whilst it is entirely wanting in sarcophagous marsupials.

Summarising, it appears that Koala only differs in its visceral anatomy from other Phalangers by the existence of its special gastric glandular apparatus, closely resembling the Wombat (*Phascolomys Wombat*) in this respect, but differing widely from this animal in the possession of a long cæcum, and in the absence of a vermiform appendix. In Koala, moreover, there is no enlarged sacculus, simulating a second cæcum such as Owen describes as being present in the Wombat.[1]

March, 1881.

NOTE.—*June* 15. Since correcting the proof sheets of the above, I have, through the courtesy of the author, received a copy of Mr W. A. Forbes's paper on "Some Points in the Anatomy of the Koala" (*Proc. Zool. Soc.*, 1881). Mr Forbes, who had the advantage of dissecting a fresh specimen, describes the vaginal *culs-de-sac* as quite distinct and free, there being no communication between them. This condition he regards as a characteristic feature of *Phascolarctinæ*. Mr Forbes gives also an admirable description of the Brain, Heart and main vessels, and of the Lungs.

[1] Notes on the Anatomy of the Wombat, *Proc. Zool. Soc.* 1836, p. 50.

ON THE LYMPHATICS OF THE PANCREAS.

By George Hoggan, M.B. (Edin.), and Frances Elizabeth Hoggan, M.D. (Zurich), M.K.Q.C.P. (Ireland). (Plate XXIV.)

Although the pancreas is an organ which, from its position, is in a manner practically removed from all surgical interference, and in which it is almost hopeless to expect that a knowledge of the course of its lymphatics will enable us to detect clinically in the living subject the course of any disease specially involving the lymphatic system, nevertheless the lymphatic system in the pancreas possesses special interest for two reasons. In the first place, except that efferent lymphatics have been seen to emerge from the organ, nothing whatever seems to be known of its intrinsic lymphatics at the present day, and it appears to have enjoyed almost unique immunity from the rash and vague guesses which compiling anatomists have so liberally made regarding other more accessible organs like the bladder and uterus. In the second place, the pancreas may be taken as the type of the racemose glands throughout the body, such as the salivary and lachrymal glands, in none of which, to our knowledge, has any attempt ever been made to discover the existence or arrangement of the lymphatic system. The result of any satisfactory investigation into the lymphatics of the pancreas may therefore be held, from the similarity of the general anatomical structure of these glands, to be equally applicable to them all. Our ignorance in this respect is probably due partly to the comparative massiveness of these glands, and partly to the fact that they are so embedded in or surrounded by other tissue, that it would be difficult, in the event of any lymphatics being found in their immediate neighbourhood, to decide whether they belonged to the gland itself or to the contiguous tissues. At first sight, it would appear that their massiveness would render the glands unsuitable for imbibition by silver solution, which we hold to be the only trustworthy method at the present day; but there appears to be no reason why investigators should not have attempted investigations by the injection method, as

has been done in the case of the liver, kidney, ovary, and even the spleen; for anyone who did not hesitate to investigate the latter organ by means of the injection method, and to publish the results thereof, ought not to have hesitated afterwards to undertake a similar investigation on any other organ in the body. As, however, the investigation by means of coloured injections of the organs referred to has, even when undertaken by illustrious investigators, only saddled anatomical science with a burden of error which we shall afterwards illustrate in this paper, it may be considered fortunate that no similar attempts have been made or succeeded on the pancreas and other racemose glands. Thus, our task will be narrowed to giving the facts as we find them, and there will be no alleged facts, already enjoying the advantage of possession of anatomical minds, to disprove.

The pancreas is an organ to the study of which the advantages of comparative anatomy are peculiarly applicable. Although in man and the larger mammals it is a massive, solid organ, yet in some of the smaller mammals, the rodents for example, it is, we believe, the unique example of a naturally dissociated large racemose gland, which can be investigated not merely by silver and staining fluids for its lymphatics, but also for the rest of its component tissues, all of which can be suitably prepared without injury to the gland as a whole, and made perfectly transparent under the microscope. In the rodents, more especially and conveniently in rats, mice, and rabbits, the pancreas is spread out upon the mesentery like a fruit tree on a wall, the branches being represented by the various ducts, of which the terminal twigs continually anastomose, and the leaves being represented by lobules of acini of the gland, thin enough, after staining, to be rendered perfectly transparent for microscopical investigation. In fact, here we have an almost perfect natural dissociation of the gland substance, so that the development, as well as the relation of all the component tissues in the adult, can be perfectly studied, not only in the gland itself, but in their approaches to it, in the clear, transparent, gelatinous matrix of the mesentery, which intervenes between the lobes of the gland.

The manipulation necessary for investigating these structures is extremely simple. Only one apparatus, the histological rings

invented by us, is absolutely necessary. In the case of the rabbit, which we have found to be the most advantageous, the rings ought to be about 1½ inch in diameter; this will generally be found large enough to include the whole of the pancreas. Immediately after the animal has been killed, the abdomen is opened widely in the mesial line. The omentum and the greater part of the small and large intestine are laid over to the right, so as to expose the duodenum and its mesenteric attachment. On the anterior surface of the mesentery, with the arborescent pancreas spread like an espalier upon it, there will be observed another portion of the intestine, with its mesentery lying like a loop adherent to the duodenal mesentery, midway between the root and the attachment of the mesentery to the duodenum. Holding the duodenal portion of the intestine firm with one pair of forceps, the other portion may be gently torn or separated from it, so as to leave the pancreas supporting mesentery intact; but at the same time the act of separating the two mesenteries will have left what may be called the anterior surface (in the natural position) of the pancreas denuded of endothelium, and specially suitable for imbibition of silver solution. The attached intestine may now be lifted up and its mesentery kept distended, while the lower ring is placed upon its anterior or denuded surface, and the upper ring jammed upon it from the opposite uninjured surface. The tambourine thus formed may then be excised with scissors from its connection to the spine and the intestine, and one or both surfaces of the membrane as it is now stretched upon the rings may have a 1 per cent. solution of silver poured quickly on and off, when after a short exposure it may be well washed with ordinary water. This preparation must afterwards undergo excessive exposure as compared with other tissues, in order to bring its lymphatics into view. Moreover, as it is generally advisable to stain the whole membrane with hæmatoxylin, so as to show the nuclei of the cells, it is well to expose it even to what may appear an injurious extent, as the process of staining seems subsequently to remove the brown tint to a large extent. The logwood-staining fluid is to be filtered upon it in the usual way, and when found sufficiently stained the membrane is well washed and clarified with alcohol and oil of cloves.

All this time it must be understood that the mesentery forming the membrane stretched between the rings has been touched by nothing except the different fluids. Shortly after clarification the membrane may be excised as a disc, and although thin as gossamer, it will retain its evenly spread out condition, so that if it be found suitable it may be at once mounted as a permanent preparation in varnish, without a wrinkle in its whole extent and without any injury to its surface. Between, however, its being subjected to the silver solution and its permanent preservation as a preparation, two or three days may require to elapse, during which it may be examined, when convenient, for the development of the image of the lymphatics. It will generally be found that the lymphatics are best seen, or only seen, on the inner (the originally denuded) surface of the tambourine membrane, as on the outer surface the serous endothelium of the peritoneum remains uninjured and well shown by its silver markings, while at the same time the endothelial cells interfere with our success, by preventing the silver solution from penetrating to a sufficient depth to demonstrate the lymphatics on that surface of the gland.

There is about the lymphatics in this tissue the peculiarity that they require a comparatively high power in order to be recognised. A power of from 250 to 400 diameters should be used, and the crenated edges of the lymphatic endothelium must be the only permissible mark of recognition. The crenated edge of the endothelium of the lymphatics in this region, for some reason as yet inexplicable to us, appears to be specially well marked, as seen in figs. 4 and 8. In figs. 4 and 8, every one of the cells was outlined by the camera lucida, and the crenation there renders their recognition absolutely certain. When the lobules of the gland have been deeply stained, the lymphatics lying upon them will be recognised easily, even under a low power, by being of a much lighter blue or purple tint upon the dark purple background, in consequence, apparently, of the endothelium of the double lymphatic wall having protected the gland cells beneath them from the imbibition of the logwood staining fluid, the crenated lines being, however, previously sought for as a test of identification. Before we proceed to the description of these lymphatics, let us first give a *resumé* of the

opinions hitherto held, and held at the present day, with reference to the lymphatics of the pancreas.

Many of our best known workers who have made personal investigation into the general lymphatic system, do not even refer to the pancreas. Of these Teichmann is a notable example. Of those observers who do mention it, Cruikshanks appears to have been the earliest, and of its lymphatics, he says, at page 166 of his work on the lymphatics: "That the pancreas has lymphatics, I am well assured. I have seen them on a great many occasions rising out of the pancreas and joining the splenic plexus." Haller did not believe that the pancreas had any lymphatics, and he pointed out that the pancreas, in which other authors had previously asserted they were to be seen, was not the true pancreas but the mesenteric glands. Mascagni, at page 50 of his great work, says: "The lymphatics which come out of the pancreas follow the course of its blood-vessels, and enter the glands to which the splenic lymphatics pass, but have no connection with those of the liver or intestine." Cruveilhier, at page 491 of the 3d edition of his *Anatomie Descriptive*, says: "The lymphatics of the pancreas are not well known; it is probable that they enter the glands nearest to them." In *Quain's Anatomy*, 8th ed. vol. ii. p. 397, we are merely told that "its lymphatics terminate in the lumbar vessels and glands," and, in vol. i. p. 511, that "lymphatics emerge from the pancreas at different points, and join those derived from the spleen." Frey, at p. 491 of his *Histology*, 3d ed., says that "the lymphatics of the pancreas are numerous, but they require more minute investigation." Finally, we come to Sappey, who appears to be the latest investigator and author who has referred to these lymphatics. In his *Anatomie Descriptive*, published in 1870, p. 831, he states: "Their investigation is very difficult; nevertheless I have twice succeeded in injecting them. They come out of the pancreas at different parts of the superior border of the organ, and join the glands near the cœliac artery." In short, it will be seen by our extracts that, although several investigators have seen lymphatics extrinsic to the pancreas, not one has seen them within the organ, or pretends to describe, or even hint at, their probable relationship to the component tissues of the gland.

When we have placed before us what appears to be a thoroughly successful specimen of a pancreas of one of the rodents, prepared according to the method we have described, in order to demonstrate its lymphatics, we must carefully bear in mind that there is one source of error to be eliminated from our search. As the pancreas is spread out upon the mesentery, we naturally have near it, and sometimes upon or within it, the main efferent lymphatics, or lacteals, passing from the intestine to the receptaculum chyli. These, at first sight, might be taken to represent the lymphatics of the pancreas, and we, ourselves, were, at the beginning of this research, partly led astray by the presence of these lymphatics, which often lie in the line of the main chains of pancreatic lobules. Having, however, been made aware of this source of error, it is easy practically to eliminate it from interfering with the special lymphatics of this research. The efferent lymphatics or lacteals in question can always be recognised by means of their straight and regular course. Although formed by the junction of smaller branches on the side of the intestine, and even by the extrinsic efferent lymphatics of the pancreas, they remain of regular calibre, with valves at regular intervals, and as they grow larger by the junction of other channels, strengthening elements in the shape of smooth muscle-cells get applied to them externally, isolated and scanty at first, but forming a very respectable coat sometimes before they reach the receptaculum chyli. In most cases, the greater part of their course lies within the transparent gelatinous matrix of the mesentery, where they may be seen to receive efferent lymphatic branches from the pancreatic lobules. In the smaller rodents, like mice and rats, this elimination is much more difficult to make, but in the rabbit, from which we chiefly took the special material for this research, there is no difficulty whatever in making it. In figs. 2 and 5, for example, it scarcely requires the foregoing caution to enable us to state that the irregular and erratic lymphatics seen passing up through the axis of the chain of lobules are certainly not the efferent lacteals, but the efferent lymphatics of the pancreas itself, receiving tributaries from various parts of the surfaces of the individual lobules.

Although, physiologically, we have here; as elsewhere, only

two divisions, namely, the collecting and the efferent lymphatics, yet for the sake of anatomical description we must divide the latter category into two subdivisions, and this too independently of the efferent lymphatics, or lacteals proper, of the intestinal canal, which we have just eliminated from consideration. No one can find much difficulty in differentiating the broad network of vessels almost destitute of valves which form the collecting lymphatics proper of the organ, as shown in figs. 1 and 3, from the irregular lines or loops of valved lymphatics which lie in the axis of the lines of pancreatic lobes, and intertwine with the blood-vessels and pancreatic ducts in that locality, as seen in figs. 2 and 5, giving off branches, at nearly right angles to the efferent stream, which pass round or between the lobules to join the groups of collecting lymphatics on the opposite side of the lobes, as seen in figs. 2 and 6. These lymphatics we speak of as intrinsic efferent lymphatics, and they, with their collecting lymphatics, form the special lymphatics of the pancreas, of whose existence, condition, or relationships nothing has hitherto been known, or even suspected. While, however, the main efferent lymphatic stream seems to pass down in the axis of the chain of pancreatic lobes, we observe, as we follow it under the microscope, that comparatively large lymphatics pass off at frequent intervals from the chain of lobes and its intrinsic efferent lymphatics, and turning backwards wend their way through the mesentery, either to join the receptaculum chyli, or, as is most frequently the case, they join after a longer or shorter course one of the great efferent lacteals from the intestine, passing through the mesentery on its way to the receptaculum chyli. The lymphatics alluded to correspond to the vessels referred to by the writers we have quoted, and, although lying within the same field of the microscope with the other vessels, and, so to speak, within the area of the pancreas, we speak of them as the extrinsic lymphatics of the pancreas. The relation of such a lymphatic to the intrinsic efferent lymphatics is seen at *c*, fig. 5. After leaving the lymphatics seen in the axis of the lobes in that drawing, the extrinsic efferent trunk remains of regular size, and no longer forms loops or anastomosing branches. We have not drawn the straight efferent lacteals we referred to as sources of error, as to do so

would be unnecessary for this research, they being too well-known to histologists to require special delineation for comparison. In fact, purely efferent lymphatics, anywhere throughout the body, although they may form anastomoses and networks, as, for example, on the upper surface of the diaphragm, seldom break up into irregular-sized loops and meandering channels intertwining with the blood-vessels, such as are seen in fig. 5.

The course of the intrinsic efferent lymphatics, as seen in figs. 2 and 5, follows pretty closely the course of development of the organ. Beginning as a bud from the duodenal orifice, this gland in the rodents divides primarily into two divisions, and these subsequently into many other divisions, which diverge from the orifice like the ribs of an unfolded fan. As they elongate, these ribs not only give out branch ribs, in the same general direction of divergence, but they also give off branches which pass from one chain to another at every variety of angle to the general plane of divergence. In all this development, it must be understood that the formation of the chains of lobules is preceded by the formation of the duct beyond the ultimate point of lobule formation. This is very well shown in the cross chains, where the whole duct, formed of lozenge-shaped cells, is often formed before a single lobule is developed upon it, and the first evidence of lobules as buds composed of five or six cells, forming an embryo acinus, can be observed, and the whole subsequent course of development exactly studied.

In some such cases the development of collecting lymphatics for the future chain of lobules can also be watched, and this gives us a satisfactory conception of the progress of the lymphatic arrangement for this special organ. Tracing the lymphatics back from the head of the pancreas, we find them passing, as we have stated, in the general axis of the head or primary chain of lobules, either as one or more channels forming irregular dilatations or loops, intertwining with the blood-vessels and duct, sometimes passing on one side, sometimes on the other, of the root or attachment of the lobules to the duct, as seen in the figures. From what we have already stated, it will not be supposed that, because the whole lymphatic arrangement of the pancreas developes backwards from the head of the

pancreas, like the ducts of the gland, as if parallel and *pari passu* with these ducts, the lymph stream passes wholly down those lymphatics, as the pancreatic juice itself passes wholly along the gland ducts towards the main opening into the duodenum. At various intervals in the course of the development peripherally of the axial intrinsic lymphatics, the extrinsic branches pass off often at right angles to the chain of lobules, as at *c*, fig. 5, and these, turning backwards, take a course as already stated, towards the receptaculum chyli, or join some of the efferent lacteals passing thereto from the intestine. These branches drain off the greater part of the lymph before it has run far along the axial chain. In figs. 7 and 8, from the developing pancreas of a young rat, we have an example of the development peripherally of an axial chain of lymphatics. At *i*, fig. 7, is seen a cul-de-sac offshoot that probably will finally become one of the extrinsic efferents we have alluded to, which will drain off part of the lymph from the axial lymphatic lying upon the chain of lobules, and which is developing peripherally at the cul-de-sac *h*, fig. 7, shown under a higher power in fig. 8.

As the main duct of the chain divides dichotomously, or gives off connecting branches to other tracts, the lymphatic vessel or vessels, as in fig. 5, likewise send an offshoot in the same direction, until the whole pancreatic espalier is provided with a chain of lymphatics along each branch.

In the smaller rodents, like mice, the lymphatic system is seldom seen to get beyond this stage, but in the rabbit we have a further development of special collecting lymphatics connected with the intrinsic efferents by branches passing off at nearly a right angle to the main chain of axial lymphatics. Several of those special collecting branches are seen in fig. 2; and fig. 6 shows one of them under a moderately high power. At *a* we see the branch ending as a cul-de-sac applied flatly to the mass of the lobule *en face*, this being the manner in which many of the branches end as collecting lymphatics; while *b′* and *b′* in the same figure represent branches which pass between the lobules to join more complicated plexuses on the opposite surface, similar to those seen in fig. 1, and which latter embrace the lobule in the same manner as the paper nautilus grasps its shell.

From the position of the intrinsic efferent lymphatics, and the manner in which they intertwine with the vessels and ducts of the organ in the axis of the chain of lobes, they may be described in relation to the individual lobes as lying in the hilus of each, or upon the hilus surface of the lobe; but in that position there is the clearest evidence that they never pass into the substance proper of the lobe. On the contrary, when we trace the branches given off from them, as seen in figs. 2, 3, and 6, we find them either terminating as a flat cul-de-sac on the same hilus surface, or passing between the primary lobules (not acini) which constitute a lobe, and emerging on the opposite surface from similar clefts or interstices between lobules, and joining or forming a collecting plexus of lymphatics on that surface. In this respect the lymphatic arrangements upon an individual lobe, such as is seen in figs. 1 and 3, even although that lobe be almost microscopical in size, are identical with the lymphatic arrangements which obtain on such massive organs as the kidney and spleen in the larger mammals, the efferent lymphatics being found at or passing to the hilus, and the collecting lymphatics at the opposite point in the periphery of the lobe, the whole lymphatic arrangement being, as we have so often insisted, merely a peripheral drainage system of vessels, and that drainage system of such comparatively little importance that it is often altogether unrepresented or absent, and is therefore evidently not of primary necessity.

We have already stated that in the pancreas of such a small animal as the mouse, the collecting lymphatics proper are generally absent, the intrinsic efferent lymphatics fulfilling the necessary function, but in these animals, and in innumerable instances in our preparations even of the rabbit's pancreas, large lobes, and even groups of lobes, are seen to be unprovided with any lymphatic vessels whatsoever. In the cases referred to the lobe or group may have developed upon or from one of the cross branches of the pancreatic duct at nearly the middle of the length of the duct, being separated from the rest of the secreting structure of the organ. It is easy there to examine the duct and accompanying blood-vessels on either side of the group of lobes, and to ascertain that no lymphatic accompanies them, and that therefore that isolated lobe or

group of lobes is unprovided with any lymphatics, which consequently cannot be an indispensable adjunct to these tissues. This, indeed, is only a narrow demonstration of a much wider principle, which becomes very evident when a comparative study of the lymphatics is made in many classes and sizes of animals, where in one class we find an organ destitute of lymphatics, which in another class (generally a larger one) is plentifully provided with them.

The collecting plexus of lymphatics, even where best developed upon the pancreas, as in fig. 3, presents features common to the same structures in many other organs in the body. The plexus found there might have been equally found upon or drawn from the sub-epithelial plexus of the intestinal canal (minus the culs-de-sac of the villous portion), from the greater curvature of the kidney and spleen (in the horse), from the lower surface of the diaphragmatic musculature, from the peritoneal surface of the transversalis abdominis, from the perichondrium or from the supra-pubic plexus in the mouse, and from numerous other localities in the body. In fact, there is a remarkable simplicity and similarity in the lymphatics throughout the body; differences can scarcely be said to exist, but only modifications in a general plan, of which the connecting links are always evident and easy of understanding. The innumerable specially descriptive names applied to various portions of vessels of the system—the Lymph-röhrchen, spalten, räume, the sinus, canaliculi, lymphatic sheaths, vasa serosa, &c.—are in most cases the outcome of fertile brains and clumsy injections, which have made artificially the cavities described as parts of a natural system, as we shall show in the course of this paper.

The relation of the collecting lymphatics to the other elements in the pancreatic lobes is extremely simple, and is shown in fig. 4. Huge drains, whose walls are formed by dovetailing tiles, lie upon the cellular structure of the lobe, and receive any excess of fluid that may ooze into them. No branched cells are to be detected in connection with them. This might be said to be due to the difficulty of detecting them upon the rather opaque cellular mass on which the lymphatics lie. But in fig. 8 there is no such inconvenience; the cul-de-sac there is evidently a purely collecting lymphatic. In the clear gelatinous matrix

the finest granule could be detected. The pyrogallate staining has also been applied so intensely that every nuclear or protoplasmic element in the vicinity of the lymphatic is made clearly and abundantly evident, but there is no trace of any minute channel beyond the walls of the cul-de-sac; in short, there is distinct evidence that the mythical vasa serosa or lymph-canalicular system of branched cells cannot have any existence there.

It often happens that branches of the lymphatics are observed leaving the close proximity of the lobule, and passing off for a a short distance and again returning to it, lying in the interval within the clear gelatinous matrix of the mesentery; and, as in such conditions a deep staining can be applied to its nuclei, we can form a satisfactory opinion as to the mode of development. This explains the projection of the cul-de-sac of the developing lymphatic in fig. 8. In such cases we generally find blood capillaries accompanying the growing lymphatic, as shown in figs. 7 and 8, as if these capillaries were the pioneers of the lymphatics. There is, of course, no relation between the development of the lymphatics and the development of the blood capillaries, the latter being formed of the terminal attachment and hollowing out of terminal cells, while the former has several endothelial cells in its periphery at its termination while undergoing development or extension, so that extension takes place by the interposition of new or wandering cells between the crenated margin of the lymphatic endothelium. These cells, by their growth and broadening out into lymphatic endothelium, serve to prolong the cavity of the developing lymphatic peripherally. This process can be followed by examining a series of terminal projecting culs-de-sac in developing lymphatics, similar to those in fig. 7. In fact, the development of the lymphatics resembles the growth of a capillary into a larger blood-vessel by the interposition of cells between the existing cells of its previously formed walls.

When we trace a lymphatic, or chain of lymphatics, along the axis of a chain of lobules until we reach what may be called its extreme peripheral termination, upon the last lobule of the chain, we generally find it terminate in a cul-de-sac, as in fig. 6, *a*, like a club-shaped finger-tip upon the thickest part of the

lobule, the axis of both being parallel to each other. Although, however, the tip or point of the cul-de-sac is actually broader than the channel behind it, there is never any attempt to send off small channels such as one might conceive the ultimate lymphatic radicle to resemble.

We have already stated that, owing to the protection given by the double endothelial wall of the lymphatic to the mass of the glandular tissue beneath it, the silver solution has not been permitted to permeate the mass at such points, and the excessive exposure to light which we previously urged as a necessity, while it renders the less protected surface of the glandular tissue of a dark brown colour, leaves the places covered by the lymphatics of a light blue tint, due purely to the staining of the logwood fluid. This is so well marked that there is no difficulty in recognising the course and shape of such lymphatics with powers much too low to recognise the crenated endothelium, which is alone the guarantee of a lymphatic.

In addition to the light blue images which mark the lymphatics, many other small light blue spaces may be observed upon the mass of the lobule that might be taken to be points of culs-de-sac of lymphatics penetrating the organ, and as evidence of complete permeation of the lobule by branches of the lymphatic system, such as exist almost unanimously in theory, but never in fact. When such isolated light blue patches are examined by a high power, more than sufficient to show with beautiful clearness the crenated edges of the contiguous lymphatics, it will be observed, in the first place, that such spaces possess no crenated lines which would argue the presence of a lining of lymphatic endothelium. Further examination will show that those spaces represent the crevices between the contiguous ultimate lobules, or even acini, of the gland. When in the living condition the silver solution was momentarily applied to the tissues, these lobules or acini being close together prevented the silver solution from penetrating between them and staining them. The subsequent extended exposure to hæmatoxylin allowed, however, that staining fluid to colour all the elements of a light purple tint. When, subsequently, the tissues were dishydrated by alcohol and essential oil a certain amount of contraction took place, more or less, but unequally, in the

different elementary tissues, so that the acinus, or lobule, shrinking from the contiguous acini, or lobules, left often a distinct interval or crevice, easily recognisable under the microscope.

The clearly demonstrated existence of such spaces leads us to one of the gravest considerations in connection with the whole anatomy and physiology of the lymphatic system, as built upon the results of comparatively late researches made by the most distinguished histologists of Germany in particular, and the arguments which we are about to bring forward ought to have the effect of destroying all confidence in the correctness of the results arrived at by those observers, pending further investigation. That spaces, crevices, or cavities, such as we have described, actually exist within our preparations, admits of no manner of doubt, by simple microscopic observation; and it is equally evident that, were the canula of an injecting syringe plunged at random into the solid mass of the gland, such cavities would certainly be the first to be filled by the injected fluid, and the cavities thus injected would be described as being parts of the lymphatic arrangement of the organ; for the injection method shows only the casts of cavities, whether natural or artificial, and offers no guarantee like the crenated endothelium to stamp the characters of the lymphatic system. Probably, in such an injection, some lymphatic channel would also be opened into and injected, and this would lead to the filling and distention of the efferent valved lymphatics extrinsic to the organ, which would seem to confirm the relation of such cavities to the lymphatic system, but in reality would only confirm a gross but almost universal error. We have long been aware of this error in a large number of researches into the lymphatic system by means of coloured injections, we having, by long study of the system by means of the silver method, acquired an almost indefinable consciousness of what is and what is not a lymphatic in such injections; but it is only lately that we have been able to explain the cause of it, and ultimately to reproduce at will a demonstration of the process in operation under the microscope, a process which we propose to describe.

What we have said of the production of the blue spaces or cavities in the pancreas is equally an explanation of the cause of error, or rather of the existence of the spaces in other tissue

and organs, which probably do not exist during life. The application of what are known as hardening or fixing fluids, produces a certain almost imperceptible change in the volumes of the different elemental tissues of the body. The amount of this change, however, varies considerably in different elements, as, for example, between the protoplasmic element, or cells, and the gelatinous matrix which binds the cells together in groups. In consequence of this, when a tissue formed of these different elements is exposed to the same hardening fluid, whether alcohol, chromates, or Müller's fluid, the differential contraction in the volume of each respectively, causes, so to speak, a shrinking of the one element away from the other. In the pancreatic tissue under consideration, we saw that either the cell-formed acini or lobules shrink away from the gelatinous matrix, or from each other, so that spaces are left where formerly the tissues were in apposition. Such spaces are not, however, found only between the acini or between the acini and the gelatinous matrix of the mesentery, in which the gland-tissue lies more or less embedded, but also around the blood-vessels, ducts, and even the lymphatic vessels themselves. When a tissue has been prepared by fixing or hardening fluids (and we generally find the observers we shall afterwards allude to recommending this preliminary hardening as indispensable for a successful injection of the lymphatics), the consequence is that the cavities thus artificially formed are the first injected, and they are afterwards described as the lymphatics of the part. Now for the demonstration of the fact.

If we take the pancreatic tissue under consideration, stretch it firmly upon our histological rings, and apply the silver solution so as to demonstrate the locality and cells of the lymphatic vessels and gland acini, stain it slightly with hæmatoxylin so as to show the exact character of all the tissues, wash it and dishydrate with alcohol in the usual way, and clarify with oil of cloves, naturally enough the thin gelatinous membrane of the mesentery will be more quickly clarified than the smaller and outlying lobules of the gland which follow next in order. (We shall suppose that clarification is effected by pouring a few drops of oil of cloves on a sheet of glass upon which the reversed tambourine is placed, and gently heated from time to time).

The large lobules forming thick masses of acini, are the last to yield, and require slight heating from time to time, to complete the process; but when that process is all but complete, it is stopped while only a shade of haziness remains in the centre of the larger lobules, which are generally those nearest the head of the gland. The all but completely clarified disc must now be excised, and a bed of very thick varnish (or balsam) having been prepared for it on a slide, it is deposited thereon, a sufficient quantity of the same thick varnish placed upon the tissue, and the cover-glass applied and pressed down. If, now, the preparation be gently heated, a minute quantity of vapour will become developed from the centre of the incompletely clarified lobules, and from the centre of the axial group of blood-vessels, ducts, and lymphatics. The slide may now be placed under the microscope, and the whole process observed step by step. The vapour is noticed extending by little jumps, passing upwards along the outsides of the vessels as an immense beautifully branched air-bubble, whose ramifications appear black by the transmitted light of the microscope mirror. From the group of axial vessels it passes on to the periphery of the lobule, sending on its black slender processes, as at fig. 9, so as to form a network between the acini in the mass of the lobule and upon its surface, filling, especially, the very light blue spaces we have been considering some pages back. It does not travel within the lymphatic trunks and blood-vessels, but so completely surrounds or ensheaths them externally as to demonstrate satisfactorily, even to the most sceptical observer, the mistake of the whole hypothesis of lymphatic sheaths of blood-vessels, nerves, &c., upon which so many fabulous theories stand at the present day, in medical science. Here we have an exact reproduction of the errors existing in numerous researches on the lymphatics of organs, which can be watched, step by step, under the microscope.

These appearances are, however, not permanent, but may disappear in from a few hours to a few days, according to the amount of moisture left in the preparation after clarification and embedding in thick varnish. The more complete the vapour injection the more confused the image of the whole gland becomes, in consequence of the closeness of the vapour

injected network, and the irregular refraction of light, which adds to the confused appearances. On this account it is difficult to draw, even by the camera lucida, and as, moreover, the most correct drawing given by us would still be liable to suspicion of unconscious deception, we were fortunate in getting our friend Mr Fowke, of the British Medical Association, to photograph directly under the microscope, a preparation of pseudo-lymphatics such as we have described, and we think it well worthy of being represented in fig. 9, copied direct from the microscopic photograph by the lithographer. The photograph was taken a few hours after the preparation had been made, and the latter now shows no trace of the former vapour injection, which has become absorbed by the varnish. It will be understood that a satisfactory demonstration can only be obtained from an uninjured tissue; an ordinary cut section would not reproduce it, and one may vary infinitely the kinds of tissue experimented upon. The muscular abdominal wall of a mouse shows this process in action very well. In it the vapour passes around and between the muscular fibres of each layer, and thus, with the three layers of the transversalis, external and internal oblique, we have the lines of vapour lying across each other according to the direction of the fibres in each layer. In the walls of the urinary and gall bladders, the vapour injection follows the direction of the felted bundles of smooth-muscle fibres, so as to give an exact reproduction of certain drawings of the lymphatics in similar tissues.

Before passing from this question, let us offer a few examples of the errors we have referred to, which may be examined in proof of what we have advanced. In Ludwig and Zwarykin's paper on the lymphatics of the dog's kidney, figs. 15 and 16 reproduce the errors we have described, fig. 15 by injection, and fig. 16 as the natural result of an amazing preliminary process of rendering the kidney artificially œdematous by ligature of the ureter during life, leading naturally to the grotesque and grossly erroneous appearances described as lymphatics. In Tomsa's paper on the lymphatics of the spleen, all the nine figures are drawings equally erroneous. In Macgillivray's paper on the lymphatics of the liver, figs. 7 and 10 reproduce the erroneous artificial injections seen round the vessels of our preparations of

the pancreas; figs. 1, 3, and 9 are also errors. Of Leopold's paper on the lymphatics of the uterus, fig. 8 is entirely wrong. It does not show a single lymphatic, and fig. 7, while it shows the lymphatics correctly in its lower half, shows a large number of what he calls lymphspalten, lymphrohren, &c., which have actually no existence. As that figure is probably a section from one of the uteri on plate i., we may take the whole of the figures in that plate to be equally erroneous.

In an article on the structure of the uterus, in the *Medicinskt Archiv* of Stockholm, for 1867, Lindgren gives in fig. 2, plate iv., what he considers to be a view under a high power of the main lymphatics of the mucosa of the neck of the uterus, with lymphatic radicles proceeding from them. The two lymphatics lie parallel to each other, and between them lie a large number of branched cells in a transparent matrix. The blue injection fills the two lymphatics, and branches off from them along the spaces in which lie the so-called branched cells of the connective tissue. The drawing bears the stamp of honesty, as a reproduction of the appearances seen, and, taking these appearances as they stand, they form a complete demonstration of the theory that the radicles of the lymphatics are the cavities surrounding, or in which lie, the cells of the connective tissue. But the whole thing is a deception. The great blue cavities, shown as lymphatics, are not lymphatics, which have everywhere complete walls formed of endothelium, unlike the spaces seen in Lindgren's drawing, and the cells separated from their matrix, by means of contraction of their substance, have allowed a certain amount of the blue fluid to penetrate between them from the large spaces. We have referred at some length to this example, on account of its value as an instance of the artificial cavities we have described. This list might be greatly extended, but the examples we have quoted may serve to show the serious character of the errors which at the present day are accepted as facts.[1] It will

[1] While the present paper was in the hands of the printer, an article remarkably illustrative of the mistakes we deprecate has appeared in English. It is a research by Dr E. Klein on the lymphatics of the skin, and appears in the report of the medical officer to the Local Government Board. This research is illustrated by twenty coloured plates, seventeen of these being of the lymphatics of the skin of the Mammalia. In our opinion not one of the latter represents the lymphatic system. Nothing could be more beautiful than the manner in which the coloured injection has followed the course or sheaths of the blood-vessels, breaking up into small branches as they break up, exactly as in the deceptive

be, however, understood that all researches into the lymphatic system by the injection method are not equally fallacious. The plates in Teichmann's splendid work on the lymphatics, and Ludwig and Schweigger Seidel's drawings of the lymphatics of tendon and aponeurosis may be instanced as examples of apparently absolutely correct injections.

The general lessons taught by the existence of the errors we have pointed out are:—(1) the lymphatic system of the solid organs, which have only, as yet, been investigated by the injection method, may be considered practically unknown, and the former opinions erroneous; (2) the results obtained by the injection method ought never to be depended upon, except where they have been confirmed by the silver method.

It has been a great misfortune that the method of silver imbibition or injection should have succeeded to the methods of injection by mercury and coloured masses, as, had the order been reversed, there cannot be much doubt that at the present day little would have remained unknown of the lymphatic system. Unfortunately, silver solution can only be applied to surfaces, but the injection method may still prove a valuable auxiliary in showing the connection between lymphatics on opposite surfaces, when once these have been previously demonstrated by silver, so as to avoid the risk of future mistakes, in injecting non-lymphatic cavities.

At the present day, there is no reliable method for investigating the lymphatics of the pancreas, where the organ forms a solid mass, any more than in the case of any other special solid organ. If the injection method were to be used, or had ever been used, in that organ, it would only reproduce the erroneous and misleading appearances seen in fig. 9, and we are glad to have had the opportunity of demonstrating what the cause and character of those appearances would be before they had obtained a footing as recognised facts in anatomy, as is already the case with

process described by us, but in a fashion never found in the lymphatic system. In this way Dr Klein not only demonstrates lymphatics within the papillæ, where normally they never exist, but, by forcing the injection between the epidermic cells, he demonstrates lymphatic radicles in the sweat glands and hair follicles. In the text Dr Klein criticises in a not unfriendly manner the methods employed by us in a similar research, but it appears that he wrote either before or in ignorance of the existence of our extended and illustrated article on the lymphatics of the skin published two years and a half ago in the *Journal de l'Anatomie*. We only regret, in the interest of scientific truth, that we find occasion to answer his criticisms by such a wholesale condemnation of the method which has led astray so distinguished an histologist as Dr Klein.

the lymphatics of the other organs we have specially referred to. Although it may have appeared wandering from the special subject of this paper to have referred to them, yet the causes and examples of these errors are so general, and easily explicable, that we thought we could do no better, when showing the source of the errors, than give crucial examples in point from accepted researches of the most capable and renowned investigators in this department of research.

The results that we have obtained from the pancreas of rodents, in regard to the lymphatic system, can be easily and correctly applied to the solid pancreas of the larger mammals, and also to the large racemose glands throughout the body, by supposing the dispersed lobules compressed together in a mass. The following conclusions may therefore be taken as generally applicable throughout the series:—

1. *Accompanying the axial arrangement of blood-vessels and pancreatic ducts, one or more irregular efferent lymphatics will be found intertwining with the other vessels, and forming at times a network around these.*

2. *These efferent lymphatics are largest where the other vessels and ducts are largest, and they divide dichotomously with these vessels, as they pass to subordinate lobules of the glands.*

3. *As the lymphatics approach the individual lobules, they lie on the hilus surface, and give off branches which spread over each lobule on its external or peripheral aspect, and terminate either as broadened out cul-de-sac terminations, or in the general form of loops or meshes.*

4. *When* (hypothetically) *a racemose gland is surrounded by other tissues, the main efferent lymphatics pass directly from the gland to the surrounding tissues, instead of passing to the termination of the main duct of the gland.*

5. *In the pancreas, although the great chains of axial intrinsic efferent lymphatics tend towards the opening of the main duct, little of the lymph within them reaches that point, being drawn off from the axial lymphatics by extrinsic efferent branches passing off at nearly right angles from them. These pass either backwards along the mesentery to join the receptaculum chyli, in rodents, or at the superior border, to join the lymphatics lying along the splenic artery in man and the larger mammals, as described by Sappey and others.*

Description of Plate XXIV.

Drawings made by the aid of the Camera Lucida.

Fig. 1. View, under very low power, of several groups of collecting lymphatics, *a*, *a*, in the pancreas of the rabbit; *b*, small portion of intrinsic efferent lymphatics; *d*, *d*, lobes of pancreas; *e*, *e*, vessels and nerves passing through mesentery, $\frac{1}{6}$.

Fig. 2. View, under similar power, of the intrinsic efferent lymphatics in the pancreas of the rabbit, $\frac{1}{6}$.

Fig. 3. Enlarged view of a portion of the group of collecting lymphatics seen in the centre of fig. 1; *f*, *f*, points where the collecting plexus becomes continuous with the efferent lymphatics on the opposite side of the lobe. Only the lobules and acini are shown in this drawing, $\frac{1}{100}$.

Fig. 4. Greatly magnified view of a portion of fig. 3, showing the pancreatic cells, *g*, forming acini, the capillaries *e*, and their relation to the lymphatic *a*, $\frac{1}{300}$.

Fig. 5. Group of intrinsic efferent lymphatics from the pancreas of the rabbit, showing an extrinsic lymphatic *c*, passing off from the intrinsic efferent group to join the efferent lacteals lying within the mesentery, $\frac{1}{18}$.

Fig. 6. Enlarged view of a portion of intrinsic efferent lymphatics, breaking up into branches which pass between the pancreatic lobules to join the collecting lymphatics on opposite surface of lobe. At *c* is an efferent lacteal lying upon the lobe, into which the intrinsic efferent branch *b* subsequently opens, $\frac{1}{100}$.

Fig. 7. Lymphatic in course of development upon the pancreas of a young rat. The cul-de-sac termination *h* appears to be the peripheral extension of the lymphatic, while the cul-de-sac *i* appears to be the prolongation backwards of what will become an extrinsic efferent lymphatic, $\frac{1}{80}$.

Fig. 8. Greatly magnified view of the cul-de-sac *h* in fig. 7, showing its relation to the wandering cells *l*, *l*, blood capillaries *e*, *e*, and nuclei of peritoneal endothelium *m*, *m*. The cells *l*, *l*, are the so-called fixed branched cells of the connective tissue, which have no connection with the lymphatic, $\frac{1}{200}$.

Fig. 9. Pseudo-lymphatics, as they appear in the pancreas of a mouse, the dark-coloured ramifications being merely artificially and intentionally made channels, filled with air or vapour, which by refraction appears black. This view was photographed direct from the preparation under the microscope, by Mr Francis Fowke; *d*, pancreatic lobules; *j*, pseudo-lymphatic branches; *k*, main channel, $\frac{1}{100}$.

In the above figures the following letters apply equally throughout; *a*, collecting lymphatics; *b*, intrinsic efferent lymphatics; *c*, extrinsic efferent lymphatics; *d*, pancreatic lobes; *e*, vessels and nerves; *f*, junction of efferent with collecting lymphatics.

Figs. 7 and 8 are from preparations stained with silver and pyrogallate of iron; all the others are stained by silver, gold, and hæmatoxylin.

CASE OF PRIMARY CANCER OF THE FEMUR.

By ROBERT MAGUIRE, M.R.C.S. (PLATE XXV.)

(From the Pathological Laboratory of the Owens College.)

AMONG the malignant tumours which primarily attack bony tissue, the sarcomata occupy the most prominent position, and have been shown to form by far the greater number of those growths which, until very recent times, were known as cancers of bone. Modern science, by unravelling the confusion which existed between the two great types of malignant tumours, has, indeed, shown that the carcinoma, in its primary form, is one of the rarest of bone tumours, but many eminent pathologists would go farther than this. Believing that cancer cells are invariably the descendants of pre-existing epithelial cells, according to the theory of Thiersch and Waldeyer, they assert that it is impossible for carcinoma to occur primarily in a non-epithelial structure, or in an organ developed from the meso-blastic layer of the embryo. Since, then, bone belongs to this class of structure, it would be impossible for primary cancer to be found there. But, although it must be admitted that they are of rare occurrence, many cases of cancer occurring in meso-blastic structures have been described; and while, in the present paper, I have reported a case of carcinoma of bone which I have myself examined, I have also endeavoured to collect the recorded cases of bone cancer which were of primary nature.

The specimen I examined was taken from a patient who was an inmate of the Manchester Royal Infirmary, and I am in-debted to Dr Dreschfeld for permission to make use of the tumour, and for his kind assistance in the examination. The clinical history, briefly stated, was the following:—The patient had first noticed a swelling of the right thigh, which increased in size, and in a little while he complained of some difficulty of breathing, and swelling of the arms. On admission there was found œdema of both arms, and of the right leg, and there was a little dulness under the first rib of the right side. There was diagnosed a primary tumour of the femur and a secondary

tumour in the thorax, pressing on the superior vena cava. This diagnosis was confirmed *post mortem*, when, after a careful examination, there were found the tumour of the thigh described below, and in the chest some enlarged lymphatic glands which had become matted together and had pressed on the vena cava superior.

The tumour of the thigh occupied the inner side of the neck and upper part of the shaft of the right femur, and appeared as a globular mass, reaching from the base of the head of the bone downwards for about 4½ inches. On section it was seen that the tumour was very friable, and contained numerous cavities. It apparently grew from the external portions of the bone, and was covered by a thick layer of fibrous tissue, continuous with the periosteum.

Sections made after decalcification showed that the tumour consisted, in its most perfectly developed part, of large alveoli communicating with each other, filled with cells, and their walls formed by a fibro-nuclear tissue (see fig. 1). The cells contained in the alveolus were of an epithelioid character, each containing one round nucleus with nucleoli, and a somewhat large amount of granular protoplasm. At the circumference of the alveoli the cells were more closely packed than elsewhere, and assumed somewhat of a columnar character, but in the centre of the alveolus they become rounder and a little smaller; no interstitial tissue was seen between the individual cells. The stroma consisted of fibrous tissue, with spindle and round cells, and in some places giant cells were found, but these were only seen in those parts of the stroma near the normal bone. Blood-vessels were not abundant in the stroma, but, when present, had their normal structure. Masses of old blood-pigment were also found in the stroma. It was evident, then, that the tumour was a true cancer. The epithelial character of the cells, the absence of intercellular matrix and of embryonic elements in the walls of the blood-vessels, the distinct alveolar arrangement of the cells, and marked separation of stroma and alveolar contents, distinguished it from an alveolar sarcoma with which it could possibly be confounded.

The development of the tumour was very interesting. The periosteum as it approached the tumour became infiltrated with round cells, which increased in quantity the farther the tissue

was traced into the region of the tumour. The periosteum was thus found to be connected with the stroma of the cancer. The bone itself was in some parts in process of absorption, and in others the bone corpuscles were in a state of proliferation, but I could not satisfactorily trace any connection between them and the cells of the stroma. These cells, as the alveoli were approached, increased in size, and assumed the characters of the intra-alveolar cells, so that it would appear, from some portions of the sections, that the intra-alveolar cancer cells were produced from the round cells of the stroma. So far, this would very much correspond with the description given by Cornil and Ranvier of the origin of cancer in bone. They describe first, inflammation of the bone, which gives rise to a mass of embryonic cells. This they call the stage of hesitation, for these cells may again develop true bony tissue, giving rise to sclerosis of bone. But if there should be a determination to cancer, then some of these cells form fibrous tissue, which encloses some of their fellows, and these latter, increasing in quantity, develope into cancer cells, while the fibrous tissue forms the alveoli.

But in the present tumour another possible source of the cancer cells appeared. I have mentioned that in the stroma a quantity of giant cells were found. Now these in some places could be seen to break up into several smaller cells by their nuclei surrounding themselves each with a separate mass of protoplasm. There was thus produced a mass of cells which could, it is true, be observed in many cases to become continuous with the other cells of the stroma; but in some parts, and this was best seen where a giant cell was situated near an alveolus, the various cells produced by the splitting up of the giant cell had the same characters as the intra-alveolar cells, and thus the space originally occupied by the giant cell became a cancer alveolus (see fig. 2).

The diseased lymphatic glands in the chest presented, on examination, the ordinary appearance of cancer. The cancer cells were more uniform; the stroma showed no giant cells.

In the above case a careful examination was made of the epithelial surfaces of the body, and there could be no doubt that any possible primary growth on such surfaces was not overlooked. We have, then, in the body only two cancerous masses.

If we assume, as the history of the case seemed to declare, that the cancer of the femur was primary, and that of the lymphatic glands secondary, the case is quite incompatible with the theory of Thiersch and Waldeyer. Professor Butlin, in his recently published lectures, says that the discovery of an alveolar structure in a bone tumour should at once suggest a doubt of its primary nature. But if, in the present case, we doubt the primary nature of the bone affection, we must assume that it was secondary to the disease in the glands, and we have, nevertheless, to do with a mesoblastic structure. Such a view would, however, agree either with Köster's theory of the origin of cancer from lymphatics, or with that of Ranvier, who believes that it developes from endothelium. The case might also be explained, but in a much less satisfactory manner, by the application of the so-called "atypical" theory, it being supposed that during embryonic life a few epithelial cells had become imbedded in the mesoblast, these having lain dormant for a long time, but having suddenly increased in quantity and formed the cancerous tumour described.

I will now mention some reported cases of cancer of bone in which the affection appeared to be primary.

In vol. xix. of the *Pathological Transactions* there is an account of a primary tumour of the lower jaw removed by Mr Christopher Heath, and this, when examined by the Committee of Morbid Growths of the Pathological Society, was declared to be encephaloid cancer. The patient died from recurrence.

In vol. xxii. of the *Pathological Transactions* is an extremely interesting case reported by Dr Moxon, in which cancer of the colloid variety occurred primarily in several bones, and secondary growths were found in the glands.

In the *St Bartholomew's Reports* for 1879, Mr Walsham reports two cases of primary cancer, one in the humerus the other in the femur.

Mr Norton (*Lancet*, Nov. 9, 1878) records a case of primary cancer of vertebræ and sacrum. At the *post mortem*, cancerous disease was found in the right ileum, the mesenteric and lumbar glands, the kidneys, and thorax. No detailed account of the microscopic examination is given.

In the same volume of the *Lancet*, and also in the *Pathological*

Transactions for that year, there is a case by Dr Braidwood of unilateral cancer affecting the left ileum, left mesenteric glands, and certain of the bones of the skull. The rectum was not removed, but was probably healthy.

During the discussion of the above case at the Pathological Society, Dr Sturge mentioned a case of cancer of the ileum, with secondary deposits in the lungs and petrous bone, in which the rectum was healthy.

Mr Pridgin Teale (*British Medical Journal*, July 23, 1870) reports a case of cancer of the femur, with secondary nodules in the lungs. No details of the microscopic examination are given.

Mr T. Holmes (*British Medical Journal*, 1880, vol. ii.) reports, for Dr Lightfoot, a case of malignant sub-periosteal tumour of the femur which was removed by amputation, and the patient recovered. The tumour was examined by a pathologist in Edinburgh and declared to be cancerous.

In the *Glasgow Medical Journal*, vol. xiii., a case is reported in which Mr M'Leod removed a tumour of the humerus, which was examined by Dr Coats and found to be carcinoma. There was also a family history of cancer. In this case also the patient recovered, and thus absolute proof of the primary nature of the disease, by examination of all the epithelial surfaces, was not obtainable, but this may safely be assumed from the clinical features of the case.

Dr Busch (*Berliner Klinisch. Wochenshrift*, 1877, p. 178) records a case of cystic epithelioma of the inferior maxilla, in which there was no affection of the mucous membrane of the mouth. He explained the case by the "atypical" theory, and said that this was the third case of the kind which he had examined.

In the following cases I have not had access to the original papers, and can only quote them from the Year Books, &c.

Schott (*Dissertat.* Giessen, and mentioned in *Virch. Archiv.* vol. xxxiv.) describes three cases of primary cancer in bones, in one of which the cancer was multiple, and after some time secondary nodules were found in the mamma.

Sudhoff (*Dissert.* Erlangen, and reviewed in *Virchow and Hirsch. Jahresbericht*, 1875, vol. ii.) gives a case of cancer in several vertebræ, the spinal cord being free; metastatic tumours

being found in the liver, and in the sternum, and other bones. The tumour resembled glandular cancer.

Witt (*Virchow and Hirsch. Jaresbericht,* 1871, vol. ii.) describes two cases of primary cancer occurring in multiple form in the bones.

Doutrelepont (*Sitzungs. d. Med. Rhein. Gesellschaft, zu Bonn,* 1879, p. 415) reports a case of spontaneous fracture of a femur in which two carcinomatous tumours were found.

Vialettes (Montpellier, 1879)—epithelioma of the upper jaw.

Staples (*Minnesota Med. Soc. St Paul,* 1879)—medullary cancer of the humerus.

Allen (*Austral. Med. Journal,* Melbourne, 1880)—cancer of the os innominatum.

Cornil and Ranvier, in their *Text-Book of Pathology,* assert that they have examined many cases of primary bone cancer. Wilks and Moxon also state their belief in its occurrence.

The figures accompanying this paper were drawn by Dr Young, Pathological Registrar of the Manchester Infirmary, whose kindness I wish gratefully to acknowledge.

ON A CASE OF CHRONIC LOBAR PNEUMONIA. By THOMAS HARRIS, *Student of Medicine at the Owens College.*

(From the Pathological Laboratory of the Owens College.)

AMONGST the chronic forms of lung disease those comprised under the term of fibroid phthisis occupy a special class, and present, both clinically and pathologically, special features of their own. A glance at the different treatises and text-books will at once show that under this term several separate affections are included, which have only a few points in common, such as, for instance, the limitation of the process to one side in most cases, the excessive induration and retraction of the lung tissue, the dilatation of the bronchi, and the excessive thickening of the pleura, whilst in the fundamental process which leads to these appearances they differ; thus, whilst some authors apply the term of fibroid phthisis as synonymous with chronic interstitial pneumonia, and separate altogether from phthisis, others include under this head different forms of chronic phthisis (with or without tubercles) having only the considerable fibroid induration of the lung tissue as the common factor.

M. Charcot, in his lectures before the Faculté de Medecine, reported in *Revue Mensuelle*, 1878, attempted to bring some order where, until now, so much confusion prevailed. Seeing with others that we have to do here with the terminal stage of different forms of an inflammatory process, having its starting-point within the lung alveoli, or in the interalveolar tissue, or in the pleura, he includes them all in the class of "chronic pneumonia," of which he distinguishes three groups:—

The Chronic Lobar or Chronic Croupous Pneumonia.

The Chronic Lobular Pneumonia.

The Pleurogenic Phthisis.

As the first of these three forms is of great rarity, I beg to be permitted to report a case which had been under the care of Dr Dreschfeld at the Manchester Infirmary, and to whom I am indebted for considerable assistance in compiling the present paper.

The case clinically presented most of the features of chronic

pleurisy with retraction, whilst pathologically it proved to be a case of chronic lobar pneumonia of the lower left lobe, with subsequent interstitial pneumonia of both upper and lower lobe. The examination of the lungs presented some other points of more than ordinary interest, some of which I may mention at once, namely,—the change of the exudation within the alveoli into fully formed fibrous tissue; the presence of a good deal of interstitial deposit, which caused excessive *contraction* of the larger bronchi instead of dilatation, as is usually the case; and the presence of typical tubercle elements in the affected part of the lung, though to the naked eye this showed neither caseation nor cavitation, and the other healthy lung and the rest of the organs were perfectly free from any tuberculous deposits.

The clinical history of the case is briefly this:—

John T., æt. 65, admitted Jan. 10, 1879, had an acute attack of inflammation of the lung (according to his account) fifteen months before admission, ever since which he had been troubled with cough and expectoration.

The physical examination showed retraction of left side of thorax, with a drawing inwards and downwards of the lower ribs, and a corresponding curvature of the spine (which symptoms, according to Walshe, only occur in pleurisy with retraction); the apex beat of the heart visible in sixth intercostal space in the left axillary line; chest movements of left side were very deficient; percussion of left side gave dulness both in front and behind, except in infraclavicular region, where percussion note was slightly tympanitic; fremitus absent from left side, except in infraclavicular region, where it was increased; breath sounds absent over the whole of the dull region. In the infraclavicular region there was heard tubular breathing, with ægophony on patient speaking.

The right side of the chest showed nothing, but compensative emphysema, together with bronchitis. The sputum was profuse, thick, tenacious, contained neither blood nor elastic fibres. The temperature normal; pulse 60, slightly jerky; all other organs normal.

The case resembled thus in every particular a case of chronic pleurisy with retraction.

The physical symptoms as regards the lungs remained the same

during the further progress; there was never any hæmoptysis, never any signs of bronchiectasis.

A fortnight after admission there supervened acute pericarditis, giving rise to loud friction sounds, but not to any increase of cardiac dulness, nor was it accompanied by any pyrexia; soon after there came on swelling of the left leg from thrombosis of the left femoral vein; swelling of the left arm also supervened. The œdema gradually subsided, but the general condition of the patient became rapidly worse from an asystolic condition of his heart, and he died on Feb. 16th. Throughout the whole duration of the case the temperature had been normal or subnormal. The urine normal in quantity, of average specific gravity, was always found free from albumin.

The *post-mortem* examination showed, besides the lung affection to be immediately described, adhesions of recent date between heart and pericardium, dilatation of right side of heart, thrombi in left femoral and subclavian veins, infarcts in the spleen, and commencing cirrhosis of the liver.

As regards the lungs, the right was found the seat of bronchitis, emphysema, and congestion of the lower parts, otherwise it showed no changes. The left lung was found retracted, so as to leave the heart, which had been pushed considerably to the left, uncovered to a great extent; the lung was firmly united to both costal pleura and diaphragm, so that it could only be removed with great difficulty. A longitudinal section through the whole lung showed the lower lobe to be one solid, uniform, firm mass devoid of air, its cut surface smooth and not granular, the colour of the section varied; some parts, especially near the periphery, were reddish, others had a greyish appearance, whilst in other places there appeared smaller yellowish spots of softened and altered lung tissue. Firm white fibrous tracts intersected the lung, some of them passing inwards from the thickened pleura which surrounded the lungs; others, and these by far the stronger tracts, surrounding the larger bronchi and blood-vessels, and increasing in thickness towards the hilus, where the main bronchus and the pulmonary vessels were completely encircled by the fibrous tissue; the bronchus being thereby very much diminished in its lumen, so as scarcely to allow a crow quill to pass; the pulmonary artery, besides being

narrowed, had its walls drawn into folds by the surrounding tissue in the fashion of a lady's work basket. The bronchi throughout the lobe had their lumina diminished in size, and everywhere surrounded by firm white fibrous tissue, in which small masses of pigment were seen, otherwise this lobe was singularly free from pigment, and only showed small thin wavy black lines near the smallest bronchi and at the circumference of the lung.

The upper lobe presented a totally different appearance; it was very much diminished in size, could be cut only with great difficulty, and its cut surface consisted of firm, slate-coloured, fibrous masses, separated by irregular cavities filled with detritus; it had much more the appearance of the lung in Corrigan's cirrhosis. Most of its bronchi dilated.

The pleura formed a thick firm capsule of more than ½ inch in thickness surrounding both upper and lower lobe. At the root of the lung were found enlarged, highly pigmented, glands, imbedded in fibrous tissue.

On microscopic examination the upper lobe was found to consist chiefly of fibrous tissue, with excessive masses of granular pigment; in many places no alveolar structure could be made out; in other places, especially near the circumference, a firm, fibrous, thickened, interalveolar tissue was seen surrounding smaller alveolar spaces, and these were filled with flattened epithelium, taking the logwood staining well. But for the pigmented stroma these parts looked very much like an epitheliomatous growth. The change of the lung epithelium to the flattened epithelium, however, is seen in many cases of chronic pneumonia and phthisis, and it has been recently described by many observers (Friedländer, Charcot, Martin). In no part of the upper lobe were there seen any tubercles; the cavities seemed to form irregular ulcers, communicating with bronchi, the detritus which was found in them consisting of granular debris.

The lower lobe, microscopically examined, showed a different and more varied appearance. In many places, especially near the periphery of the lung, were seen patches which showed typical croupous pneumonia, the alveoli still filled with fibrine, small cells, and few red blood corpuscles, the interalveolar tissue, however, thickened and composed of young embryonic

elements. In other parts of the lung the alveolar arrangement had completely disappeared, and was replaced by a more or less fully formed fibrous tissue, with round cellular elements, which took the staining well.

In some parts this uniform fibrous tissue showed a compressed bronchus and artery in its centre, and masses of pigment surrounding these canals, and was, therefore, evidently a chronic peribronchitis; in other parts, however, no such canals could be seen, while, on the other hand, the arrangement of the fibrous tissue resembled more in its outline the lung alveoli. A portion of this young fibrous tissue, no doubt, was nothing more than increased interalveolar tissue; another part, however, seemed to have its origin from within the alveoli, and transitional stages were seen, which showed the correctness of the view, for between the stage of croupous exudation and that of complete organisation, a gradual change from one to another could be observed, different parts showing the various stages of the process of the transformation of the inflammatory products within the alveoli into fibrous tissue. Thus in some regions the alveolar wall was seen somewhat thickened, while within the alveoli existed a mass of cells, chiefly of the round variety, and with these some little fibrine was still perceptible. In other parts, and apparently as a later stage of the same process, the cellular contents of the alveoli become more numerous and closely packed, and, at the same time, their nuclei became distinctly oval, while the fibrine was no longer to be seen.

In many parts the intraalveolar mass could not be distinguished from the alveolar boundary, and its separate origin from this proved, but in others this was most distinct and evident, a fibrillated nucleated tissue being contained within the alveoli, and quite separate and distinguishable from the alveolar wall. The intraalveolar fibrous tissue was found to contain capillaries, and in some places these seemed directly to proceed from the capillaries in the alveolar walls. On comparing the several transitional stages, it seemed more than likely that the exudation cells within the alveoli were chiefly concerned in this organisation, while the endothelial lining cells of the alveoli had little or no share in the process, a view which has also been adopted by other observers (Coupland, Marchand).

The spots, which to the naked eye appeared softer and more friable, were found, microscopically, to have the structure of tubercle, and consisted of a granular, not easily stained, centre, in and immediately around which giant cells, with many nuclei, were visible, and a peripheric part, consisting chiefly of small round cells, closely packed, and easily stained, with a small amount of fibrillar matrix.

These small tuberculous masses were very abundant; they were often seen also in parts, which, to the naked eye, presented no signs of softening. Their relation to the different lung structures could not be made out; they were, however, only found in those parts where the pneumonic process had reached the last stage of organisation, and where the fibrous masses of the latter seemed to pass gradually into the small celled growth at the periphery of the tubercle.

The epitheliomatous appearance described above as seen in the upper lobe was nowhere seen in the lower lobe.

As regards the condition of the bronchi, many sections exhibited large tracts of fibrous tissue, with the lumen of the bronchus in the centre contracted, but not otherwise altered; in the lumen of the larger bronchi, firm plugs were found, consisting of fibrine and granular masses.

It will be seen from the description, that this case, which during life resembled a case of pleurisy with retractions (for there was retraction of the left side of the thorax, drawing in of the lower ribs, displacement of the heart towards the left, and the dulness on percussion, absence of fremitus and of breath sounds owing to the obstruction and contraction of the bronchi), is a case of chronic lobar pneumonia.

The patient's history gives evidence of an acute febrile attack sixteen months before his death, and the examination of the lung shows large tracts yet in a state of red and grey hepatisation. It is not uncommon to find true croupous inflammation in cases of chronic phthisis, never, however, are these found in such large and connected tracts as in this case; we have further to notice that the affection is confined to one lobe, and occupies the whole of that lobe, which could scarcely be the case if the process was any other than lobar pneumonia.

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In some parts this uniform fibrous tissue showed a compressed bronchus and artery in its centre, and masses of pigment surrounding these canals, and was, therefore, evidently a chronic peri-bronchitis; in other parts, however, no such canals could be seen, while, on the other hand, the arrangement of the fibrous tissue resembled more in its outline the lung alveoli. A portion of this young fibrous tissue, no doubt, was nothing more than increased interalveolar tissue; another part, however, seemed to have its origin from within the alveoli, and transitional stages were seen, which showed the correctness of the view, for between the stage of croupous exudation and that of complete organisation, a gradual change from one to another could be observed, different parts showing the various stages of the process of the transformation of the inflammatory products within the alveoli into fibrous tissue. Thus in some regions the alveolar wall was seen somewhat thickened, while within the alveoli existed a mass of cells, chiefly of the round variety, and with these some little fibrine was still perceptible. In other parts, and apparently as a later stage of the same process, the cellular contents of the alveoli become more numerous and closely packed, and, at the same time, their nuclei became distinctly oval, while the fibrine was no longer to be seen.

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Seeing then that the primary affection was an acute pneumonia,

or rather pleuro-pneumonia, we have here the rare occurrence of the pneumonic intraalveolar exudation undergoing organisation, and becoming fully formed fibrous tissue. This termination is one which has only recently been made the object of closer study; it is noticed by Green, Goodhart, and more recently by Coupland (*Path. Trans.* 1879, p. 224), who describes a case somewhat similar to the one which is the subject of this paper, and in which the same intraalveolar changes could be followed.

Marchand (*Virch. Arch.* vol. lxxxii. p. 317), describes the same changes in several cases of acute croupous pneumonia, and believes, also, that the exudation cells are the elements from which the fibrous tissue is formed, a view which is also held by Coupland (whose paper seems to have escaped Marchand's notice), and to which the appearances seen in the above case give a strong support.

Besides the lobar pneumonia, we have to notice in our case a very considerable amount of interstitial pneumonia, in the form of excessive tracts of fibrous tissue, surrounding the bronchi and blood-vessels, and found also in the interalveolar spaces. Some of these bands proceeded inwards from the pleura, by far the greater portion, however, developed primarily in the interstitial tissue and around the bronchi, where it was found much more abundantly than at the periphery of the lung.

The contraction of the bronchial tubes described above is a most unusual symptom. Charcot had already drawn attention to the fact, that in chronic lobar pneumonia the bronchi are not dilated, and in Coupland's case they were but little dilated. This is, however, not invariably so, as was pointed out by Wilson Fox (*Reynold's Syst. Med.* vol. iii. art. "Ch. Pneumonia"). The absence of dilatation in these cases is probably due to the intraalveolar deposit, rendering the lung impervious to air, and being in itself, by virtue of its organisation, the cause of the retraction of the lung.

Two other points remain to be noticed, the want of pigmentation and the presence of tubercles in the affected lower lobe. As to the first of these two points, I think it is easily explained when we consider, that from the first the lung alveoli were the seat of an exudation, and that subsequently the bronchi became

contracted; very little pigment could thus reach the alveoli, and still less could be deposited in the interstitial tissue, as it would have to traverse the organised alveolar contents. As for the presence of tubercles, this, no doubt, is a very rare complication. From their position there can be no doubt that they were of later date than the pneumonia, and were implanted upon the fully formed organisation; that they bore some relation to the affected part is shown by their limitation to the pneumonic lobe, the rest of the organism remaining free. As for the upper left lobe its condition is interesting when compared with the lower lobe. It was contracted, consisted simply of firm black fibrous bands, with large irregular cavities, which, in a few places, could be seen connected with bronchi. The bronchi, except near the lower and inner part of the lung, were found dilated. It was thus a typical specimen of chronic interstitial pneumonia, and differed from the lower lobe in the absence of intraalveolar organisation, in the presence of large masses of pigment, in the presence of dilated bronchi, and in the presence of a peculiar epithelium in some of the lung alveoli, a condition which Dr Dreschfeld found in another case of chronic interstitial pneumonia, and which will be the subject of a separate communication.

From the above description, I think it becomes clear that we had here first a pneumonia or pleuro-pneumonia of the lower lobe, and that afterwards both lobes became affected with an interstitial fibrous growth, and a gradual chronic thickening and infiltration of the pleura.

The peculiar physical symptoms seen during life, the dilatation of the right side of the heart, and the formation of thrombi in the veins, are easily explained and require no comment.

A CONTRIBUTION TO THE PATHOLOGICAL ANATOMY OF PRIMARY LATERAL SCLEROSIS (SCLEROSIS OF THE PYRAMIDAL TRACTS). By J. DRESCHFELD, M.D., M.R.C.P., *Professor of Pathology, Owens College.* (PLATE XXVI.).

SEVERAL years have now elapsed since Erb and Charcot described, the former under the head of "Spastic Spinal Paralysis," the latter under the title of "Tabes Dorsal Spasmodique," a special form of chronic spinal disease, chiefly characterised by a gradually progressive paresis (advancing from below upwards), accompanied by muscular rigidity, contractures, and increased tendon reflexes. The clinical features of this group of symptoms, especially the spastic gait, "are so well marked" that the disease is easily recognised, and it was soon found that the spastic spinal paralysis is by no means a rare affection, that it may occur in very young children, and that in some cases it proves amenable to treatment. The clinical symptoms being thus very precise, it became an important question whether they were due to a distinct and idiopathic disease of the spinal cord, or merely the outcome of other and various affections. From the symptoms, both Charcot and Erb believed the disease to be due to a "symmetrical progressive sclerosis of the lateral columns from below upwards, especially in their posterior parts." These theoretical considerations have, however, so far not been verified by the results of the *post-mortem* examinations on cases which, during life, presented more or less the typical symptoms of primary lateral sclerosis, and several observers, notably amongst whom Leyden (*Berl. Klin. Woch.* 1878, No. 48), began to doubt the independent existence of such a disease.

Amongst a number of cases with the typical symptoms of lateral sclerosis, which my friend and colleague Dr Morgan had under his care in the Manchester Infirmary, and some of which he described in the *British Medical Journal*, January 29, 1881, there was one which ended fatally, and where the spinal cord showed such characteristic lesions in support of Charcot and

Erb's views, that I beg to be permitted to describe in detail the lesions found in that case, especially as the short report I appended to Dr Morgan's paper is brief and incomplete.

The clinical history of the case is given by Dr Morgan in his paper already quoted; and it showed paralysis of the lower extremities, with marked contractures, increased tendon reflexes (of both upper and lower extremities), absence of any sensory or trophic disturbances, of any bladder troubles, or any brain symptoms. The patient died from a thrombosis of the femoral vein, followed by pyrexia and septicæmic symptoms.

The *post-mortem* examination, conducted by Mr Hodgson, then resident house physician, showed a soft purulent thrombus in the left femoral vein, small deposits in the lungs, great fluidity of blood, slight ecchymoses on pericardium, enlarged softened spleen, swelling of the solitary follicles and Peyer's patches in the intestines.

The brain, medulla, and spinal cord were examined by me at the time with the necessary care.

The brain and its coverings showed no lesions whatever. The dura mater normal, its veins not immoderately filled with blood. There were a few Pacchionian granulations. The pia mater normal; neither thickened nor abnormally vascular. The brain itself of normal size, colour, and consistence. Numerous sections through the brain displaying the motor area of the cortex, the internal capsule, and the adjacent parts at each side showed no naked-eye changes; the ventricles were not dilated; the peduncles normal. Sections through the pons and medulla showed these parts normal, both as regards consistence, colour, and vascularity.

As regards the spinal cord, its membranes were found of normal thickness and vascularity; no adhesions. The cord itself showed to the naked eye no changes except slight softening in the lowest dorsal region. Sections made through the cord, at small distances from each other, showed to the naked eye no abnormality.

The spinal cord and medulla, with portions of the pons and brain, were put in bichromate solution for microscopic examination; when sufficiently hard, sections through the cord showed already to the naked eye one light-coloured patch in each lateral column; this patch was particularly well marked in the

dorsal region, and became less markėd in the cervical and lumbar regions.

The microscopic examination of sections stained in carmine showed again the portions of brain and medulla which were examined to be free from any changes, with the exception of the anterior pyramid in the lowest portion of the medulla, which showed an increase of the neuroglia and the presence of a great many Deiter's cells. Some of the axis cylinders swollen and some atrophied.

The upper cervical, and some of the region of the cervical enlargement, showed a small sclerotic patch close to the posterior horns, extending forward, but not reaching the anterior horns, and extending but little outward in each lateral column. The direct pyramidal tract in each half at this region took the staining better than the rest of the anterior column, and showed an increase of the neuroglia.

The lesion in the lateral columns became much more pronounced in the lower portion of the cervical enlargement. Here the sclerotic patch occupied almost entirely the lateral pyramidal tract, and also the direct pyramidal tract on each side (see fig. 1). In the lateral tract the sclerotic patch was in close relation to the posterior horn; receding from it as it passed forward anteriorly it did not extend to the anterior grey matter, and externally it did not reach the external border of the white matter. The direct cerebellar fibres were therefore perfectly free from disease, so were the posterior columns; Burdach's as well as Goll's tract. As for the grey matter no pathological lesion could be detected in this part of the spinal cord either in the anterior or posterior horns.

In the upper dorsal region the lesions were the same. The large motor ganglia cells showed perhaps some more pigment than is ordinarily found; some of the cells also seemed separated from their processes, and the central group of cells had fewer cells than is usually found here. But beyond these changes no further lesions could be observed in the grey matter. As for the sclerosis in the pyramidal tracts, it occupied exactly the same position as in the cervical, but extended a little further laterally in the lateral columns. The sclerotic patch in the left lateral column extended somewhat further outward than

in the right (during life the left leg was found to be more affected than the right).

In the lower dorsal region, whilst the lesions in the lateral columns were very pronounced, and occupied the same extent as in the upper dorsal, the sclerosis of the direct pyramidal fibres was still indicated by increase in Deiter's cells and neuroglia generally. The grey matter showed here marked atrophy and pigmentation of some of the cells of the central and antero-lateral groups, whilst the internal group and the postero-lateral group, and also the cells in the vesicular column of Clarke were normal (see fig. 2).

In the softened part of the cord which occupied the lower and part of the lowest dorsal region the cord was a little out of shape, the anterior horns being pushed slightly backwards and outwards, and thus causing the posterior horns and the lateral columns to assume a slightly crescentic form on each side. Microscopically it is clearly seen that this appearance is simply due to pressure and not due to any disease, for the sclerotic patches in each lateral column appear with great distinctness, whilst the rest of the white matter is normal, and the grey matter presents the same changes of the cells as in the dorsal region just described.

In the lumbar region the sclerosis occupied a triangular patch, bounded internally again by the posterior horn and deviating a little from it as it passed forward, whilst externally it came up close to the periphery to the cord; it did not reach so far anteriorly as in the dorsal or cervical region. No other part of the white matter was affected. As for the grey matter, the internal group, the postero-lateral group, and the vesicular column of Clarke were normal. The rest of the cell groups were in some places scarcely visible, in other parts they were found, but while some were still normal, and showed their processes, others were atrophied, shrunk, without nuclei, often highly pigmented (fig. 3). The neuroglia of the grey substance in the regions where the ganglia cells were found affected showed the presence of a quantity of granular matter. The blood-vessels, however, were not found affected.

The sclerotic portion in the lateral columns, when examined with a high power, showed engorgement of the blood-vessels,

increased thickness of their walls, and perivascular deposits of small cells. The neuroglia showed excessive increase of Deiter's cells, numerous oval and round nuclei, which took the staining well, and a quantity of fine fibrillæ. The nerve fibres had in some places quite disappeared, in other places they were simply reduced to axis cylinders, which were either atrophied or hypertrophied. In the anterior pyramidal tract, throughout the cord, the lesions were of less intense character, the blood-vessels especially showing no change. In those parts of the cervical region where the lesions were so very limited, the changes were equally confined to the neuroglia, the nerve fibres showing few changes beyond a swelling of their axis cylinders.

From the above description it will be seen that we had here to do with a distinct systemic lesion affecting the whole of the pyramidal tract in the lumbar and dorsal and lowest cervical region, and part of the pyramidal tract in the upper cervical regions, extending slightly into the anterior pyramids of the medulla. Beyond an atrophy of the ganglia cells in certain groups of cells in the anterior horns in the lumbar and lower dorsal regions, the rest of the cord was found perfectly normal. As for the changes in the ganglia cells, I cannot help looking upon these as secondary to the sclerosis of the pyramidal tract, for they are absent in those parts of the cord where the sclerosis is in a less advanced stage; there is also the absence of any alteration in the blood-vessels in the grey matter, which would scarcely be missed, if the disease originated primarily in the grey matter—a fact which I again recently had occasion to notice in a case of amyotrophic lateral sclerosis which had been under the care of my colleague Dr Leech; further, the appearance of the affected cells themselves, showing nearly all the different degrees of atrophy, and lastly, the distribution of the atrophy. It will be seen that the cell groups which remain intact are the internal and postero-lateral groups, while the central and antero-lateral groups were found affected. Now, in those cases of old hemiplegia with contractures, in which, after years, the ganglia cells in that half of the cord which is the seat of the descending sclerosis undergo atrophy, the distribution seems, according to Pitres (*Arch. de Phip. Norm. et Path.* 1876, p. 664) and Brissaud (*Récherches sur la Contracture*, p. 179)

somewhat similar—in Brissaud's case the postero-lateral group was also much affected—and there can be no doubt that in those cases the affection of the ganglia cells is purely secondary to the sclerosis.

It will be argued that in cases of cerebral hemiplegia with contractures the changes in the ganglia cells appear only very late in the course of the paralysis, and are associated with muscular atrophy and diminution in the rigidity of the paralysed limb. It must, however, be considered that in those cases the affection of the pyramidal tract is itself only a secondary degeneration, and follows soon after the onset of the primary lesion, while in the above case the sclerosis of the lateral columns is the primary disease, and therefore most likely, as such, sooner followed by secondary degeneration in the grey matter than in hemiplegic cases. If, in the above case, there was no atrophy of the muscles noticed during life, and no diminution in the rigidity of the limbs, the explanation may be found in the fact that the atrophy of the cells had, after all, not reached a very considerable degree; and many a normal ganglion cell was found amongst a group of atrophied ones. Nor is it at all a generally established fact that the resolution in the contracted limb and the atrophy of the ganglia cells go hand in hand. In the case of amyotrophic sclerosis above alluded to the contractures persisted to the end, and the corresponding regions of the cord showed most marked and most extensive lesions in the ganglia cells of the anterior horns. In further support of the view I have taken, I can cite a case of transverse myelitis of the dorsal region, with secondary descending sclerosis in the lower dorsal and lumbar region, and where, besides the lateral pyramidal tracts, the anterior grey matter was also affected, and affected in a degree similar to the above case.

If, lastly, we compare the appearance of the anterior horns in this case with the appearances seen in cases of undoubted primary disease of the grey matter, such as infantile paralysis, amyotrophic lateral sclerosis, we see most marked differences; or in those affections whole groups of cells have disappeared, the neuroglia shows marked alterations, and the blood-vessels engorged and thickened; none of these changes are seen here.

That the affection in our case is not only "systemic," but also progressive from below upwards, is seen on comparing and following upwards the lesion in the several regions of the spinal cord. Though, during life, the upper extremities showed nothing abnormal, beyond increased tendon reflexes, there are found after death distinct signs of sclerosis, though very limited, occupying the pyramidal tracts in the cervical region. Now, in three cases which I have lately had under observation, all of which seemed typical examples of spastic spinal paralysis, as yet in an early stage, the patients were not conscious of any affection of their upper limbs, nor seemed there to be any loss of power or rigidity in the arms, and yet, in all three cases the tendon reflexes in the wrist, fore-arm, and arm, were markedly increased; and the presence of this symptom seems to me to be of some importance from a diagnostic point of view, and may still further assist us to distinguish the *primary sclerosis of the pyramidal tract*—as the disease may, I think, now rightly be called—from other nervous affections, which may for a time present similar symptoms but be due to a variety of lesions, all, however, having perhaps this in common, that the pyramidal tract in some portion of its course is implicated either directly or indirectly by the lesion.

In conclusion, I beg to thank my friend, Mr A. H. Young, for the drawings which accompany this paper, which were made from specimens submitted to him, and which show at a glance, and correctly, the lesions observed in this case.

APPENDIX.

The object of the foregoing paper was simply to record the lesions of a case of primary lateral sclerosis, and to show that the group of symptoms observed in our case was due to an idiopathic symmetrical sclerosis of the pyramidal tracts of the spinal cord, wherefore I have proposed to call the affection "primary sclerosis of the pyramidal tracts." It may be not uninteresting briefly to refer to the other cases on record in which the diagnosis during life was not verified by the *post-mortem* appearances. Without entering at all into a discussion of the clinical features of the disease as foreign to the purposes for which this journal was established, it will be readily seen that many varied affections of both brain and spinal cord may give rise to some of the symptoms of this disease, especially to the "spastic gait," but that the onset and the course of the disease, and the presence of other

symptoms on the careful analysis of the case, may assist much in our differential diagnosis.

The first *post-mortem* account of a reputed case of primary lateral sclerosis we owe to Charcot (Bétaus, *Etude sur le tabes dorsal spasmodique*, Paris, 1876). The case turned out to be a case of disseminated sclerosis. It is, however, remarked by Charcot (*Leçons sur les localisations*, 2^m fasc. p. 369) that in this case there were present besides the characteristic symptoms also vertigo and tremors, which, taken into account in a second case observed by Charcot, enabled him during life rightly to diagnose disseminated sclerosis, which diagnosis was confirmed after death.

The second case is reported by von Stofella (*Wien. Med. Wochensch.*, 1878, Nos. 21, 22, 24). The affection is here stated to occupy the two lateral columns in their posterior portion, in the dorsal and lumbar regions, extending laterally from the posterior horns to the pia mater. The spinal cord was not examined microscopically, and no mention is made of the condition of the brain and medulla. It is thus doubtful whether the case was one of primary lateral sclerosis.

Schulz (*Deutsch. Arch. f. Klin. Med.* vol. xxiii. p. 346) gives the *post-mortem* examination of two cases, the clinical history of which are contained in *Arch. f. Heilk.*, vol. xviii.

In the first case a gliomatous tumor was found in the medulla, extending into the anterior pyramids. The spinal cord showed typical lateral sclerosis a little more extensive on the right than on the left side. The rest of the white matter and the grey matter was in a normal condition. In this case the sclerosis was secondary and not primary, and the symptoms, as relating to the cord observed during life, in harmony with the lesion found. Much more remarkable is the absence of any bulbar paralysis as the tumor reached up to the calamus scriptorius.

In the second case the spastic symptoms were only of short duration. Symptoms pointing to a cerebral tumor at the base of the brain came on. A small sarcomatous tumor was found between the pons and the crus cerebelli ad pontem. There was besides distension of the ventricles of the brain. The spinal cord showed no changes. The case merely shows that spastic symptoms may be present in brain-affections. The presence of cerebral symptoms in most cases would, however, prevent an error in the diagnosis.

Schulz gives a third case. The symptoms commenced here in both upper and lower extremities at the same time; there was also vertigo present. The *post-mortem* examination showed the presence of chronic hydrocephalus, the spinal cord showed no changes. In a more recent paper (*Centrbl. f. Nervenk.* 1880, p. 376), Schulz expresses the opinion that the hydrocephalus caused irritation of the lateral tracts.

Hallopeau (*Des paralyses bulbaires*, Paris, 1875), describes a case where *post-mortem* a tumor was found in the medulla and secondary degeneration of the lateral columns of the cord.

Strümpell (*Arch. f. Psychiatrie*, vol. x. p. 676) gives the account of two cases.

In the first case the spastic symptoms were very marked. There was, however, present retention of urine and hyperæsthesia of the lower extremities. The *post-mortem* examination showed the case to be one of myelitis of the upper dorsal region, with secondary degenerations extending both upwards and downwards, including also the direct cerebellar tracts which were found affected both above and below the seat of lesion.

The second case ran much more the course of lateral sclerosis. The autopsy showed sclerosis of the lateral pyramidal tracts and of the direct cerebellar tracts, caused probably by a hydromyelus which was found to extend throughout the spinal cord.

A. Friedenreich (*Centrbl. f. Nervenk.* 1880, p. 213), a case, where, besides the spastic symptoms, there were symptoms relating to the brain and medulla. The brain showed numerous blood points, the medulla and spinal cord showed multiple patches of sclerosis with hypertrophy of the neuroglia, whilst in other places the parts were softened with complete destruction of the nervous tissue. The patches had a very irregular distribution.

Schulz (*Centralbl. f. Nervenk.* 1880, p. 369) gives additional two cases. In the first there were, besides the symptoms of spastic paralysis, disturbances of sensibility and affection of the bladder. The autopsy showed the case to be due to a myelitis caused by pachymeningitis. To the naked eye there seemed to be no degeneration of the lateral tracts. No microscopic examination was made.

In the second case there was also considerable loss of sensibility, which went on to complete insensibility in the lower extremities. The case was one of transverse myelitis with secondary combined sclerosis of the lateral and posterior columns.

Aufrecht (*Deutsch. Med. Woch.* No. 18, 1880). I have only had access to the review of Aufrecht's case in the *Centralbl. f. Nervkkl.*, p. 239. According to this account the symptoms were not quite typical at the onset, though during the course of the disease they were better developed. There was complete paralysis with contractures and increased tendon reflexes. Towards the close of life, bladder and rectum became paralysed and the tendon reflexes disappeared. The *post-mortem* examination showed changes in the lateral columns in the lumbar and dorsal regions. The ganglia cells in the anterior horns were profoundly affected.

A review of the above given cases shows that where the spastic symptoms are observed we may infer that the pyramidal tracts are involved. That these symptoms may remain the chief symptoms for some time, but that when the affection involves other tracts, some new group of symptoms appear, such as disturbances of sensibility, affection of the bladder, &c. The cases given only show that primary sclerosis of the pyramidal tracts is a much rarer affection than was at first supposed; but that it does exist as an independent disease has, I think, been proved by our own case.

THE FORM AND PROPORTIONS OF A FŒTAL INDIAN ELEPHANT. By Professor TURNER, M.B., F.R.S. (Plate XXVII).

In the stores of the Anatomical Museum of the University of Edinburgh is the fœtus of an Indian elephant, which was acquired many years ago from the late Mr John Arthur. No history is attached to the specimen. As several anatomists have of late years investigated the anatomy of this animal, and as this *Journal* has been the means of communicating several of these investigations, a figure of this specimen, with some account of its form and proportions, may be of interest to our readers. Albert Seda did, indeed, before the middle of the last century, figure[1] and give a short description of the fœtus of the African elephant, but, so far as I know, that of the Indian elephant has not previously been figured.

The abdominal and pelvic viscera, together with the lumbar and sacral spine, had unfortunately been removed by an incision made along the dorsal mesial line, so that the shape of the posterior part of the body was affected. The umbilicus had been torn off, but the sheath of the penis was preserved. The head, anterior part of the trunk, and anterior and posterior limbs, were in good order.

The following dimensions were taken :—

From base of trunk along curve of back to hinder end of body, . .	$21\frac{1}{2}$ inches.
Length of trunk, ...	8 "
Length of lower lip, . . .	$2\frac{3}{4}$ "
Height at shoulder, . . .	$15\frac{1}{2}$ "
Circumference of fore foot, . .	5 "
Length of eye slit, ...	$\frac{1}{2}$ inch.

The circumference of the foot was only about one-third of the height of the animal at this stage of development, and not one-half, as is stated to be the rule in the well-grown elephant.

[1] Locupletissimi rerum naturalium Thesauri accurata descriptio, vol. i. tab. cxi. fig. 1, Amstel. 1734.

The fore arm was slightly flexed on the upper arm, and the fore foot was somewhat flexed on the fore arm, and it was not possible fully to extend the fore limb. The hind foot was flexed slightly forwards, so that the heel was prominent.

The cuticle was dark brown, and where it was shed the cutis had a dull yellowish tint. The general surface of the skin was without hairs, but short delicate hairs were present in the following localities:—the outer surface of the lower lip; the skin of the trunk, especially about and within the nostrils; the external auditory meatus; and the upper border of the tragus.

The auricle of the ear was $3\frac{3}{4}$ inches high, and $3\frac{5}{8}$ inches in antero-posterior diameter. It was thin and flattened, especially at the edges, and triangular or spear-shaped, with the apex directed backwards to the shoulder. The meatus was no larger than would admit a small catheter, and was guarded in front by a large tragus.

There were no eyebrows, and the lids were without eyelashes. A large third eyelid was present.

The surface of the trunk was marked by transverse constrictions. The median process at the free end of the trunk was distinct. The columella was situated $\frac{1}{4}$ inch within the orifice.

The cheeks were distensible. The lower lip was prolonged forwards to a point in front of the mandible. The upper lip was not quite so well developed as the lower, but was prolonged forwards to the base of the trunk. The mucous surface of the palate was traversed by feeble transverse ridges, and the free surface of the membrane between these ridges was thickly studded with short papillæ. The inner surface of the cheek was also papillated, especially in a line parallel and close to the upper and lower gums. In the presence of ridges on the palate, and of papillæ on both cheeks and palate, this animal differed from the African elephant described by Mr W. A. Forbes. The orifice of the parotid duct was seen on the inner surface of the cheek. The gums were smooth, and not perforated by the teeth.

The tongue was pointed in front, and could be drawn forwards as far as the pointed tip of the lower lip. $1\frac{1}{8}$ inch of the tongue was situated in front of the frænum linguæ. Numerous papillæ were scattered over the dorsum of the tongue, and at its posterior

parts two well-developed circumvallate papillæ were at each side of the mesial line. At each margin of the tongue several short transversely arranged slit-like furrows of the mucous membrane were seen, resembling the arrangement described by Mayer[1] in the Indian, and by W. A. Forbes[2] in the African elephant. The folds of mucous membrane between these furrows were not unlike in their position, but shorter than, the so-called papillæ foliatæ, so well seen in the tongue of the rabbit, or in the human tongue in front of the attachment of the palato-glossal fold of mucous membrane. As the papillæ foliatæ in the human and rabbit's tongue contain the gustatory bulbs, and are associated with the sense of taste, for which reason I have named them gustatory lamellæ,[3] it is not improbable that if these folds in the elephant's tongue were examined microscopically in a fresh specimen, gustatory bodies would be discovered in them. The mucous membrane of each fold between the furrows had one or two sharp papillæ projecting from it, and a distinct series of similar papillæ was prolonged forwards towards the tip of the tongue in a line with the furrows.

A single large leaf-like papilla projected from each side of the frænum linguæ, where it was attached to the under surface of the tongue. It is probable they were connected with the mouths of the ducts of Wharton, although I did not detect the orifices.

A pair of very small foramina, admitting only a very fine probe, opened at the anterior border of the mucous membrane, covering the hard palate. These were Jacobson's canals, and on pressing the mucous membrane a little fluid oozed out through these openings. Where each upper lip became continuous with the gum covering the pre-maxillary bone a row of five small openings was seen. Each led into a shallow cul-de-sac, and was probably the orifice of a mucous follicle.

The posterior buccal orifice was almost circular, and only $\frac{4}{10}$ths inch in diameter. There was no uvula.

Five nails were developed on each fore foot, but only four on the hind foot, for the rudimentary great toe had no nail.

[1] *Nov. Act. Akad. Cæs. Leop.* xxii. 1847.
[2] *Proc. Zool. Soc. Lond.* May 6, 1879.
[3] *Introduction to Human Anatomy*, part i. 1875.

Mr Carse, in his interesting memoir on the *Manners, Habits, and Natural History of the Elephant*,[1] states that the young animal at the time of birth seldom exceeds 34 inches in height, though on one occasion a young male stood 35½ inches high. The young animal, a female, recently described by Dr Chapman,[2] was 30 inches high when born, and measured from the base of the trunk to the root of the tail 35 inches. From these measurements it would seem that the specimen described in this communication was only about a half-grown fœtus.

For the drawing from which the lithographic plate has been reduced I am indebted to my assistant, Arthur Thomson, M.B.

[1] *Philosophical Transactions*, 1799.

[2] *Journal of Acad. Nat. Sciences of Philadelphia*, viii. 1880.

THE FEMORAL ARTERY IN APES.

By J. MACDONALD BROWN, M.B., *Demonstrator of Anatomy, The Owens College Manchester.*

ABOUT a year ago, through the kindness of Professor Morrison Watson, I had an opportunity afforded me of making a careful dissection of a female chimpanzee (*Anthropopithecus troglodytes*). While pursuing my investigation I was much struck by the peculiar distribution of the arteries to the leg and foot, as well as by the extreme scantiness of the literature on the subject. I therefore resolved to endeavour to ascertain as far as possible what condition existed in the rest of the quadrumana. During the past winter session I have dissected five different species, viz., *Cercopithecus Campbelli*, Waterh.; the white-crowned mangabey (*Cercocebus Æthiops*, Linn.); the dog-faced baboon (*Cynocephalus porcarius*, Bodd.); the sphinx-monkey (*Cynocephalus Sphinx*, Linn.); and the common drill (*Cynocephalus leucophæus*, Desm.). Of the first and last named monkeys I dissected two, and in all of them, to insure accuracy of detail, both legs were examined, but the differences noted were so trivial as to render it unnecessary that they should be mentioned. In order to obtain a fine injection, a mixture of size and vermilion was employed.

It is my intention in this paper to give a brief account of the distribution of the femoral artery and its branches in these monkeys, to note the condition of the arteries in the anthropoids, and to compare these with each other.

The arrangement of the apes is in accordance with the classification adopted by the Zoological Society of London in their "List of Animals."

With regard to the literature of the subject in addition to original memoirs, I have consulted the systematic works on comparative anatomy of Cuvier, Stannius, Meckel, Carus, Owen, Huxley, Vrolik, Wagner, &c., &c.; but in none of the latter, with the exception of Meckel, did I find more than the most general statements about the arteries. It seemed to me, therefore, that a brief but systematic account of the femoral artery, and the modifications which it undergoes in these

monkeys, might, if recorded, prove of some interest. To the memoirs, as well as to Meckel's observations, I shall have occasion to refer to subsequently.

I. *Cercopithecus Campbelli*, Waterh. (Campbell's Monkey).—In this monkey the femoral artery resembled very closely that of man, both as regards its relations and distribution. The profunda was somewhat rudimentary, but gave off both circumflex arteries, and, winding as in man behind the femoral trunk, supplied two perforating branches. The highest perforating artery was derived from the internal circumflex. About the middle of the thigh the femoral divided into two trunks, of which the outer—which was also the larger—passed between the insertions of the adductores magnus and longus, while the inner one occupied the usual position of the anastomotic in the human subject. This latter, which might be named the "great saphenous artery," gave off in the thigh a few muscular twigs, and an articular branch to the knee-joint in the same position as, but relatively smaller than, that in man. The artery then passed downwards, lying upon the insertion of the gracilis, the inner head of the gastrocnemius, and for a short distance upon the origin of the flexor longus digitorum. In the above course it lay along the posterior border of the sartorius muscle, and was accompanied by the long saphenous nerve. It then crossed the shin obliquely, and divided upon it into two branches, an external and an internal. Just above this bifurcation it gave off a slender branch, which ran downwards along the posterior border of the bone, and ended over the inner ankle in small anastomotic branches. This branch, we shall find, is the representative of the posterior saphenous artery in other apes, *e.g.*, the baboon. The internal artery passed downwards towards the dorsum pedis, lying upon the tibia, and in front of the ankle-joint and anterior annular ligament. It supplied the hallux and first interspace. The more external division, which was the larger, crossed the tibia, and lay in front of the ankle-joint but beneath the annular ligament. In the dorsum it divided into two branches, the larger of which ran forwards in the second interspace and entered the sole. Between it and the lesser branch an arch was formed, from which branches to 3½ toes were supplied.

About 1 inch above the ankle the artery gave off an anastomotic branch to the anterior peroneal.

The popliteal divided as in man into the anterior and posterior tibial trunks.

The *Anterior Tibial* was very small indeed, and ended by anastomosing with arteries at the ankle. Having given off an articular to the knee it supplied the tibial and fibular muscles mainly by two branches.

The *Posterior Tibial* was much as in man. The peroneal had the ordinary distribution. In the sole, however, the plantar trunks derived from the posterior tibial were extremely small, the arch being principally formed by the perforating saphenous. The digital and perforating branches call for no remark.

II. *White Crowned Mangabey* (*Cercocebus Æthiops*, Linn.).—In its dissection the first peculiarity worthy of remark was that the circumflex arteries came off from the femoral trunk, otherwise they were much as in man. There was no profunda femoris, but the perforating arteries (three in number) were derived, the superior from the internal circumflex, the lower two from the femoral. The latter vessel divided, as in the cercopithique, into two trunks, of which the external one (great saphenous) was somewhat smaller than the other. Rather above the middle of the leg the great saphenous bifurcated into two branches, anterior and posterior. The posterior was the smaller of the two, and passed downwards, lying upon the flexor digitorum longus, then entered the superficial aspect of sole running behind the internal maleolus. There it gave off numerous calcanean and anastomotic twigs, and divided just behind the tarso-metatarsal articulation into two branches, external and internal. These supplied the skin richly, and anastomosed anteriorly with deeper arteries.

The *Anterior Saphenous Artery* ran obliquely across the shin, and very soon divided into two branches while yet on its surface. The more internal of these in its course lay upon the tibia, and crossed the front of the ankle-joint, lying beneath the anterior annular ligament, then upon the tarsus and tendon of the tibialis anticus muscle, being crossed by the innermost belly of the extensor brevis digitorum, which was so distinct from the

rest of the muscle as almost to appear a separate one. The artery then ran in the second interspace (upon the dorsal interosseous muscle), and leaving it about the anterior third passed through to the sole. In its course it supplied the inner aspect of the foot, and by two large branches the first and second interspaces. In the sole it formed the plantar arch by anastomosing on the outer side of the foot with the external superficial plantar artery already referred to. In addition, it received communicating branches from dorsal arteries. From the convexity of the arch were given off three branches, which were distributed as in man to the outer 3½ toes. The hallux and half of the second toe were mainly supplied by the dorsal artery.

The external branch in its course lay upon the tibia, and in front of the ankle-joint, then in the furrow of the astragalus. It ran to the outer aspect of the tarsus, being crossed by the tendon of the tibialis anticus muscle. After having given off articular, malleolar (both sides of foot), and tarsal branches, it divided into two over the base of the 4th metatarsal bone, which arteries supplied the outer two interspaces. Just above the inferior tibio-fibular articulation it gave off a branch, which, running outwards, anastomosed with the anterior perforating from the posterior tibial artery.

The *Anterior Tibial* was of a fair size. It gave off a recurrent articular (as in man), also muscular branches, and then about the upper third of the leg divided into two trunks, which ran downwards towards the ankle. These were simply muscular, but anastomosed with branches about the ankle, as well as with several twigs from the posterior tibial, which perforated the interosseous membrane at various parts.

The *Posterior Tibial* was relatively a large artery with a distribution and course very similar to that found in man. It terminated, however, in small branches about the ankle, and was not prolonged into the sole. In its course it gave off several twigs which pierced the membrane, and anastomosed as above described. Its peroneal branch was as in man, except that it was smaller than usual. It gave off perforating and malleolar branches.

III. *Dog-Faced Baboon* (*Cynocephalus porcarius*, Bodd.).—

The description of the femoral artery in the mangabey would almost serve for that in the baboon, and indeed for the other monkeys yet to be described. So that I shall content myself with enumerating the salient points, and contrasting any little differences which may exist.

The femoral artery gave off no profunda trunk. The circumflex arteries, external and internal, arose from the femoral itself. The perforating branches were three in number, and were derived, as in the mangabey, from the internal circumflex and femoral arteries.

The *Great Saphenous* artery equalled in size the continuation of the femoral trunk. It gave off branches to the vasti muscles and a large anterior articular one. While crossing the insertion of the semitendinosus it divided into two branches, the anterior and posterior saphenous arteries.

The *Posterior Saphenous* was the lesser of the two, and ran along the posterior border of the shin, lying upon the soleus and flexor longus digitorum muscles. After having given off numerous twigs to the internal malleolus, it passed beneath the internal annular ligament and entered the sole. As it did so it was crossed by the muscles from the calcaneum to the hallux. It then gave off tarsal and metatarsal branches, and divided into external and internal plantar arteries. These were, however, very small, and anastomosed with branches from the plantar arch. The internal plantar supplied both sides of the hallux and the inner aspect of the second toe.

The *Anterior Saphenous* artery had a similar course and relations to that described in the mangabey. In its passage towards the ankle it was crossed by the two tibiales antici and by the extensor longus hallucis muscles. About 2 inches above the ankle-joint it gave off a large branch, which ran almost transversely outwards and after supplying malleolar and articular branches anastomosed with the anterior peroneal. The artery continued forwards beneath the anterior annular ligament, and gave off two large branches, one on either side, just after it had emerged from under the annular ligament. The main trunk was continued forwards in the second interspace as in the mangabey. The external branch supplied malleolar and tarsal twigs, and ended in branches to both sides of the fourth

and fifth, and to the outer aspect of the third toe. The internal artery supplied both sides of the hallux and the inner aspect of the second toe. The remaining branches for the supply of the dorsal aspect of the toes were derived from the main trunk just before it left the dorsum pedis. The plantar arch was formed in a most curious manner. Two large arteries perforated the second interspace (of which the anterior was the larger), the one just at its posterior limit, the other in the usual position. The posterior one ran almost transversely outwards across the metatarsal bases to the outer aspect of the sole, then forwards, and united with the anterior branch, thus forming the arch, which lay just behind the heads of the metatarsal bones. A small branch connected the two perforating arteries immediately after they had entered the sole, so that in the present case an arterial circle existed. As in the mangabey, the arch supplied branches to 3½ toes, the hallux and inner half of the second digit mainly receiving blood-supply from the dorsal branches.

The *Anterior Tibial* artery had similar relations and disposition to those in the mangabey. Its muscular branches were more extensive and numerous. It terminated on the anterior aspect of the ankle-joint by anastomosing with the anterior saphenous artery. One or two twigs from it could be traced to the joint itself.

The *Posterior Tibial* had the usual relations, and supplied the same arteries as in the human subject. The only differences which existed seemed to be that its muscular branches were larger, and that the peroneal artery came off at a lower level and was relatively small. The peroneal gave off no anterior branch, and its communicating one was of diminutive size. The posterior tibial artery terminated by piercing the interosseous membrane in the position usually occupied by the anterior peroneal, and none of its branches could be traced into the sole. A very extensive anastomosis existed at the back of the ankle-joint and over the malleoli.

IV. *Sphinx Monkey* (*Cynocephalus Sphinx*, Linn.)—The femoral artery was much as described in the preceding apes. There was no profunda femoris, its place being taken by branches from the main trunk as in the former cases.

The *Great Saphenous* was almost precisely as in the last monkey. Its posterior division was identical in relations, &c. with that of the mangabey, except that about 1 inch above the ankle it gave off a branch, which, running outwards on the posterior aspect of tibia, took the place of the anterior peroneal. The *Anterior Saphenous* had the same relations and branches as in the cercopithique. Its internal division supplied the first interspace and pierced the sole, anastomosing there with the plantar arch. The external artery gave off an anastomotic above the ankle, and was distributed to the dorsum as in Campbell's monkey. It entered the sole through the second interosseous space.

The *Anterior Tibial* supplied articular and muscular branches, but could not be traced as far as the ankle. It anastomosed freely, however, with two branches from the posterior tibial, which pierced the interosseous membrane at varying heights.

The *Posterior Tibial* was relatively small. It seemed to be like the last, chiefly a muscular trunk. There was no distinct peroneal, properly so called, but its fibular branches much exceeded its tibial ones in size. The artery terminated near the ankle by anastomosing with the perforating saphenous.

The plantar arch was formed by that artery which, coming through the second interspace, anastomosed with the external plantar from the posterior saphenous artery. The digital and other remaining branches were as in the mangabey and baboon.

V. Common Drill (*Cynocephalus Leucophæus*, Desm.).—The femoral was distributed as in the last case, there being no profunda artery.

The *Great Saphenous* was as in the baboon and sphinx. Its posterior division had the usual course, and ended in small anastomotic branches about the inner ankle. The anterior saphenous artery did not divide into two trunks in the leg as was the case in the cercopithique, mangabey, and sphinx; but, as in the baboon, was a single unbranched trunk giving off only small muscular twigs, and an anastomotic branch to join that from the posterior tibial. Several small branches were distributed to the tarsus and metatarsus, &c., then the artery entered the sole through the second interspace, in which also it gave off a pos-

terior perforating, so that really it communicated with the plantar arteries by two channels.

The *Anterior Tibial* was a small vessel, which, after piercing the membrane, gave off several ascending and articular arteries, and divided then into two trunks, external and internal, both of which were distributed to the muscles. One branch from its internal part seemed to anastomose with the anterior saphenous. As in the sphinx, several branches from the posterior tibial pierced the interosseous membrane at various points, and inosculated with branches from the anterior.

The *Posterior Tibial* was much as in man, except that the plantar arteries were relatively small. There was no distinct peroneal artery, but as in the baboon the anterior peroneal came from the posterior tibial itself.

VI. *Spider Monkey* (*Ateles*).—Professor Humphry[1] describes the anastomotic artery in ateles as dividing into three branches. Of these, one took the place of the anterior tibial and supplied the foot; a second supplied the hallux, and the third replaced the posterior tibial in lower part, and supplied the plantar arteries. The posterior tibial itself was small, and terminated at the outer ankle.

I propose now to describe the arterial supply of the posterior extremity in the anthropoids (*Simiidæ*). Of these I have only dissected the chimpanzee, so that for my description of the femoral artery in the gorilla, orang, and gibbon, I must refer to the accounts given by other anatomists.

(I.) *Gorilla* (*Troglodytes gorilla*).—Dr Chapman of Philadelphia[2] states that "the only peculiarity about the vessels of the lower extremity, was that of the femoral artery giving off in the middle of its course a good-sized vessel, which accompanied the long saphenous nerve, and ran to the inner aspect of the foot."

He considers it possible that the condition might have been an anomalous one, but that it existed on both sides. He proposes to call it the "long saphenous artery." The plantar arteries were as in man.

[1] *Journ. of Anat. and Phys.* vol. i.
[2] *Proc. Ac. Nat. Sci. Phil.* part iii. pp. 391, 392, 1878.

The above is the only account of the femoral trunk in the gorilla which I have been able to find.

(II.) *Chimpanzee* (*Anthropopithecus troglodytes*, Gm.)—As previously stated, I made a careful dissection, about a year ago, of a female chimpanzee. In it the femoral trunk was very similar to that in man. The profunda was present, although somewhat small, and gave off the circumflexes and perforating branches just as in man. About an inch above the opening in the adductor magnus the femoral gave off a large trunk, which, running at first almost in the same axis as the main artery, afterwards wound round to the front of the tibia. Above the knee it supplied articular and muscular branches, but until it had entered the dorsum pedis it was unbranched. It crossed the tendons of the tibialus anticus, extensor longus hallucis, and the inner one of the extensor brevis, and disappeared between the two heads of the first dorsal interosseous muscle.

The *Anterior Tibial* was as in man until it reached the ankle, when, instead of running forwards as the dorsalis pedis, it divided into two branches. Of these, the external supplied the tarsus and metatarsus, while the internal split into two parts, of which one passed round into the sole, the other anastomosed with the saphenous artery.

The *Posterior Tibial* was as in man, except that relatively it was rather smaller. In the sole, the saphenous divided into two parts, one running forwards to supply the inner toes and internal aspect of the foot, the other, passing backwards and outwards, formed, with the external plantar artery, the plantar arch, from which branches to the outer toes were given off. Humphry states[1] that in his chimpanzee, on the right side, the anastomotic supplied only the interval between the hallux and index, the rest of the lower part of the limb being supplied by the posterior tibial, which, in its course, gave off perforating branches to the muscles in front. On the left side the artery was small, and did not extend beyond the middle of the leg, the last perforating branch of the posterior tibial taking the distribution of the anterior tibial in man.

Chapman[2] found the anterior tibial extremely small, "the long saphenous" replacing it.

[1] *Journ. of Anat. and Phys.* vol. i.
[2] *Proc. Ac. Nat. Sci. Phil.* part i. p. 56, 1879.

Vrolik describes [1] the arterial condition in the leg as identical with that in man.

(III.) *Orang-Outang* (*Simia satyrus*, Linn.)—Chapman [2] here also describes the "long saphenous" artery, with a similar distribution to that in the gorilla and chimpanzee.

(IV.) I have been unable to find any description of the femoral in the genus *Hylobates*.

If we carefully consider the foregoing arterial conditions, we cannot but be struck with the remarkable gradation that is displayed by them. In order the more succinctly to demonstrate this, let me summarize the leading arteries and the modifications which they undergo.

1. *Profunda Femoris*.—This vessel, absent in the drill, sphinx, baboon, and mangabey, is present, although rudimentary, in the cercopithique and chimpanzee. In the latter it has a disposition similar to that in man, although relatively somewhat smaller.

2. *External Circumflex*.—In the first four monkeys this vessel is derived from the femoral itself; in the cercopithique it almost arises in common with the rudimentary profunda; while in the chimpanzee it is given off by the latter artery.

3. *Internal Circumflex*.—This branch, like the last, arises from the femoral in the first four monkeys, but is derived from the profunda in the cercopithique and chimpanzee.

4. *Perforatings*.—These, in the drill, sphinx, baboon, and mangabey, are furnished by the internal circumflex and femoral; in the cercopithique by the internal circumflex and profunda; and in the chimpanzee by the profunda alone.

5. *Great Saphenous*.—This vessel equals the femoral in size in the drill, sphinx, and baboon; is rather less than it in the mangabey, while in the cercopithique and chimpanzee it is considerably smaller. In all it gives off muscular and articular branches.

6. *Posterior Saphenous*.—This artery is almost identical in calibre with the anterior saphenous in the sphinx; is much

[1] *Recherches d'Anat. sur le Chimpansé*, 1841.

[2] *Proc. Ac. Nat. Sci. Phil.* 1880.

smaller than it in the drill, baboon, and mangabey, and extremely slender in the cercopithique. It is absent in the chimpanzee. The artery terminates over the inner ankle in the drill and cercopithique; it supplies the anterior peroneal and rudimentary plantars in the sphinx, while it ends in small plantars vessels in the baboon and mangabey.

7. *Anterior Saphenous.*—This is an unbranched vessel in the drill, baboon, and chimpanzee, and in the two former supplies the place of the anterior peroneal. In the other monkeys it divides into two trunks, external and internal, of which the former supplies the plantar arch in the sphinx and cercopithique while the latter does so in the mangabey.

8. *Anterior Tibial.*—In the sphinx, and probably also in the drill, this artery is extremely small, and does not extend so far down as the ankle. It is small, and anastomoses with arteries at the ankle in the baboon, mangabey, and cercopithique. In the chimpanzee, until the vessel reaches the ankle it is similar to that in man, but, unlike his, it terminates on the dorsum pedis in tarsal and metatarsal branches.

9. *Posterior Tibial.*—In the sphinx this artery is small, and ends in muscular twigs near the ankle. In the baboon its distribution is rather more extensive, and in it the vessel terminates by assuming the place of the anterior peroneal. In the mangabey it reaches but ends at the ankle. In the drill it supplies the anterior peroneal, and ends in the sole by dividing into rudimentary plantars. The artery in the cercopithique has a very similar distribution to that found in man; the plantars are, however, proportionately much smaller. In the chimpanzee it is similar to that in man.

10. *Plantar Arch.*—This is entirely derived from the saphenous arteries in the sphinx, baboon, and mangabey; chiefly from them in the drill and cercopithique, while in the chimpanzee it is mainly formed by the posterior tibial artery.

The absence or modification of the profunda femoris in these apes has not, to my knowledge, been hitherto noted. We find in the lower monkeys that the muscles of the thigh are supplied by branches from the femoral itself, and it is only, indeed, when we reach the cercopithique that a

special muscular trunk (profunda) is provided. Meckel describes[1] the femoral artery in the quadrumana as dividing, near the crural arch, into two branches, which he names the anterior and posterior crural. He states that the posterior is a muscular branch to the calf, while the anterior, partly muscular, passes to the dorsum pedis, thence into the sole. He says it is probable that this early division of the femoral is an indication of the breaking-up of this artery into a number of branches, constituting, by their interlacement, a vascular plexus, of the disposition of which some species, more or less related, offer examples. He describes the femoral artery in the cebus as dividing into two branches, a superficial muscular, and a deep which supplies the anterior and posterior tibials. Of these, the anterior, which is also the smaller, descends to the dorsum, while the posterior supplies the sole.

It seems to me that, in the first description, Meckel refers to the great saphenous vessel when he speaks of the anterior crural, and in the cebus his deep division probably represents it.

Nunn[2] states that in monkeys, while the anterior tibial is limited to the leg, the anastomotic (saphenous) passes to the foot.

Humphry[3] says that the anastomotic (great saphenous) is usually large in apes; accompanies the saphenous vein to the ankle, and supplies, to a greater or less extent, the district which, in man, is supplied by the anterior tibial, and even that by the posterior tibial. He further seeks to account for this peculiar distribution by assuming that it probably has relation to the outward bend of the knee and inward direction of the hallux in these animals, which conditions render the course along the inner side of the knee and leg the shortest and straightest to the region of the hallux.

Be this as it may, we have presented to us in the monkeys before described, a striking series of changes in the area and extent of distribution of this artery. Beginning with the ateles, sphinx, baboon, and mangabey, we find it in these supplying

[1] *Comparative Anatomy*, vol. ix.

[2] *Observations on the Arteries of Limbs*, 1864.

[3] *Journ. Anat. and Phys.* vol. i.

both dorsal and plantar aspects of the foot, thus replacing, in position and function, the tibial vessels, which are here, comparatively speaking, rudimentary. In the drill, also, the foot has a similar arterial supply, but in it rudimentary plantars from the posterior tibial are also present.

As we ascend the series, even the cercopithique resembles the last as regards the distribution of this artery to the foot, although the tibial plantars are relatively somewhat larger.

It is only, indeed, when we reach the *Simiidæ* that we find the supply of the sole to be chiefly derived from the posterior tibial. In these animals, also, there is a further approximation towards the condition in the human subject, in that the anterior tibial supplies part of the dorsum.

As regards the anterior tibial, I am inclined to think that its size and extent have been somewhat under-estimated. It is generally described as being very rudimentary, if, indeed, its presence is not altogether overlooked. Now, of the six apes I dissected, in three it could be traced to the ankle, while in the chimpanzee it even supplied part of the dorsum pedis.

In the quadrumana, therefore, the tibial arteries are, as a rule, rudimentary, or, at least, chiefly muscular to the leg, while the duty of supplying the foot with blood is relegated to a special artery, possibly, according to Humphry's theory, because, from the construction and position of the parts of the limb, a more direct course to the foot is required than that afforded by the tibial vessels.

Humphry[1] and Cruveilhier[2] compare the anterior tibial to the radial artery. Nunn, again, states that the great saphenous (anastomotic) is the analogue of the radial, but, considering the extensive distribution of the former in all the monkeys I have described (with the exception of the *Simiidæ*), we cannot but infer that in these, as in the ateles described by Humphry, the saphenous is the analogue of the radial and ulnar arteries combined.

[1] *Observations on Limbs of Vert. Animals*, 1860.
[2] *Descriptive Anatomy*, p. 758.

THE BRAIN AND NERVOUS SYSTEM: A SUMMARY AND A REVIEW. By Robert Garner, F.L.S., F.R.C.S.

In investigating the brain, the crown and summit of animal organization, enthroned in which is located that *receptive faculty* as regards the external world, ministered to by vital conductors, or nerves, the medium between the two, of a *centripetal* nature, and also that *initiatory power* of reacting the exterior through similar channels, but these *centrifugal*—in studying this organ we cannot adopt such means solely as are adopted by anatomists in the investigation of any other organ, for we have but an imperfect notion of the way in which its functions, including that mysterious one, the reciprocal action and reaction of mind and matter, are performed. We may become familiar with its morphology, or rather with the mere topography of its components, a part of anatomy, however, difficult enough to master, and we may examine its finer structure with the microscope in each locality within its boundaries, but though a few results will seem probable enough, yet there will be too few to satisfy the mind, and we shall be led to seek for further conclusions from other facts, physiological or pathological, or at least indirect in their nature. Thus in man we endeavour to appreciate the greater or less development of the organ, or its parts, according to age, sex, race, and individual, for these circumstances imply differences in faculties, and, presuming as we may that the last will be accompanied by concomitant differences in organisation, we are led to hope that herein we may find some inlet to the arriving at ideas respecting the true meaning of the brain. Thus, again, we trace the gradual complication of the nervous system upwards from the lowest to the highest animal, especially in the vertebrate series, and as regards the brain, especially in such Mammalia as have convoluted cerebral lobes. Finding the advent of any new part, or the enlargement, or diminution of any constant part, to correspond with any new faculty, or the greater or less development of any function, we hope to draw important conclusions from the same. And lastly, for similar reasons, we trace up the morphology of the human brain through its gradual development from the embryo state.

Till a comparatively recent date, the convolutions of the human brain, which we may fairly conclude from several considerations to be the portion of our bodily structure most intimately connected with our mental functions, have been given up by the anatomist and draughtsman as an indefinite congeries of the fortuitous enteroid windings of the organ in question—*a mighty maze without a plan*—no convolution having a distinct function, which probably is to some extent the case, but more than this, it has often been supposed that the cerebral faculties are so diffused through the brain as a whole that, excepting distinct functions as regards the cortical and medullary strata, *any*

portion according to its extent may perform different actions; and that one faculty or its manifestation is never confined to a single convolution or tract of medullary and consequently transmitting matter.

Such are the views advocated more or less by Brown-Séquard. Recently good service has been done by closer study of these convolutions, and by the record of the same being more accurately registered by drawing, engraving, and photography, so that now the observer's attention can be fixed to any part of the brain surface by verbal definition. Indeed, an accurate cast of the brain itself may be taken: *we* let the brain fall from the skull into a hardening solution of bichloride of mercury, the strength about 6 ounces of the salt to the half gallon of water, making a fluid of about 1038 sp. gr., or the same as the brain itself, in which it consequently remains suspended in mid-fluid, without pressure on any of its surfaces, and becoming hard and solid, without the contraction which takes place when spirit is used.

All arrangements of the cerebral convolutions at present are probably somewhat arbitrary and unphysiological, telling us too little of the action or supposed action of the organ and its parts, or at anyrate they have little foundation on the internal structure or development. It is true that a few anatomists have attempted more—Foville for instance, and Mr Swan in his later work. Perhaps it may be said that both works are very faulty, yet they appear to take account—the first of the brain's formative converging and diverging fasciæ, and of its commissural structures, the latter point enforced more recently by the observations of Dr Broadbent [1] and others—the second attempting an arrangement of the convolutions or rather of their fibrous basis, the cerebrum ovale, and lower cerebral peduncles, as these are composed of afferent or efferent, sensory or motor, tracts, and as the influence conveyed by the latter is flexor or extensor, or with regard to the convolutions which are the centres of respiratory, voluntary and involuntary, or psychical impulse.

A preliminary matter may be adverted to, treated by Professor Turner and by the author of this paper in the *Journal of the British Association*, 1862; it is a point which has as much a practical as a physiological import.[2] We may perfectly know the disposition of the brain-windings as they are called, yet be puzzled to attribute them to the particular localities of the skull to which they appertain when we view it from without or from within. This skull is more than a mere protective covering, but a fused development of several of the

[1] This gentleman considers some convolutions to have no connection with either the crus or corpus callosum, but only with other convolutions which have, and to the first he attributes the higher faculties. To the organs of sense are due on the one hand *impressions*, to the thalami crude *sensations*, and to the marginal convolutions *perceptions* administering to the first class of convolutions, where perceptions are compared and the will initiates reflex functions as the *motor*, performed through the convolutions of the second class and the corpus striatum, and also *speech* itself through the appropriate convolution.—See Lectures in the *British Med. Journal*, 1876. See also the paper of an earlier date 1870. *Journ. of Mental Science.*

[2] The author's papers are in the *Reports of the British Association*, 1860, 1861, 1862, 1863, 1869, 1870, 1876.

individual segments of the jointed carpentry of the body, and that the segmental nature of the skull is not to be disregarded is evinced in the tacit division of the cerebrum into corresponding segments, and in the nomenclature transferred to the brain from the bony case which protects it. By perforating the skull at a few points along the lines of the sutures, and marking the cerebrum at the corresponding points, by introducing a particle of vermilion by means of a grooved needle, it will be well seen where the brain and its bony covering correspond; and if a cast of the former is made, this may be permanently shown by introducing pins, head first, into the brain at the points marked, which will be drawn out with the moulds and afterwards left imbedded in the final cast, the result being not devoid of interest. The fissure of Rolando, ascending a good way from the upper margin of the fissure of Sylvius obliquely backwards to the summit of the brain, but terminating more forwards or backwards according to the greater development of the posterior or anterior convolutions, has been commonly held to separate the frontal from the parietal division of the brain, but it is thought by others, and we think properly, that the less marked line of sulci, the ascending ramus of the Sylvian fissure, under the coronal suture, is the true line of separation between the frontal and parietal convolutions, though the bases of the frontal convolutions, and the anterior of the two convolutions bordering the fissure of Rolando, from which the frontal certainly spring, are situated behind the coronal line. This fissure or line of sulci of the ascending ramus appears to exist independently of any special adaptation for the lodgement of arteries, and corresponds sufficiently with the inner parietal, or upper branch of the calloso-marginal sulcus, for both together to form a line of demarcation across this part of the brain; but a question may be, is there any physiological significance in this division, or indeed of the better-marked fissure of Rolando? This last fissure attains the middle line a little before the præcuneus. The basis of the frontal convolution seems to be annectent communications of the frontal perceptive portion of the brain with the parietal motor, forming a triangular surface, marked by a corresponding impression in the interior of the skull. Taking this view then, the frontal lobe is separated from the parietal, not by the fissure of Rolando, but rather by the ascending ramus of the Sylvian fissure, and within the longitudinal fissure by the ascension to the edge of the upper margin of the hemisphere of the sulcus or rather of a branch of it, separating the gyrus fornicatus (here girdling the corpus callosum) from the marginal; it is more or less marked in man, and situated at the end of the anterior third of the brain-margin near the junction of the coronal and sagittal sutures—better marked in animals, corresponding to a crucial fissure on the upper surface of the brain, showing in them the extension backwards of the frontal lobes, most in the higher and more intelligent, least in the lower and more obtuse species. Of these frontal convolutions, progressively added or inserted as we ascend in the animal series between the more external and posterior convolutions, we may suppose the internal one to have some relation to smell, for the crest-like tracts of this part of the brain figured by Foville are seen to

originate from the olfactory region, and ascend within the longitudinal fissure, and it may also be significant that the convolutions here are often marked by the dark colour of their arachnoid in some animals, the sheep for instance, as are their olfactory tracts and bulbs, as well as the Schneiderian membrane: of the middle frontal convolution we can say less, it may be a light centre, of the external one we must instance the theory of Broca as a matter not to be dismissed so dubiously. The occipital lobe of the brain is well separated from the parietal within the longitudinal fissure by the internal parieto-occipital sulcus, and externally not quite so obviously by sulci running in the line of the lambdoidal suture. It has the calcarine sulcus within the longitudinal fissure marking the situation of the posterior horn of the ventricle, and the upper triangular portion is called the cuneus. Thus the occipital lobe corresponds to that plate of the occipital often called the interparietal bone, sometimes even in man a distinct bone, connected by suture at the lower part to the occipital. The posterior half of the parietal lobe lying within the longitudinal fissure consists of a quadrilateral lobule so-named (or præcuneus), and before this, separated by the ascension to the superior edge of the cerebrum of the fissure (calloso-marginal) lying between the gyrus fornicatus and the margin, are the convolutions more or less separated from the inner surface of the true frontal lobe. All these convolutions within the upper portion of the longitudinal fissure have their formative fibres more or less springing from the front before the anterior bent portion or genu of the corpus callosum, in a crested fashion, owing to the mode of the original development of the brain. On the outer and lower margin of the hemispheres, or of the occipito-temporal portion, at one-third of its length from behind, is the termination of the external occipito-parietal sulcus, presenting a depression which marks the division of the temporal and parietal lobes, considerable vessels ascending here upwards and backwards, within the cranium; in this place arises the upper edge of the petrous bone, and externally the squamous suture here becomes more crenate over the mastoid process. The tuberosity of the third frontal convolution lies within the frontal bone just above its junction with the great wing of the sphenoid. The suture between the parietal and sphenoidal, when it exists, lies a little higher up over the fissure of Sylvius; in fact, it is directed almost in the same line as the squamous suture itself, which last marks the line of the Sylvian fissure, or sometimes rather of the superior temporal gyrus. This spheno-temporal or inferior lobe of the brain corresponds outwardly to the squamous process of the temporal and great wing of the sphenoid, its apex might be reached from the back and external part of the orbit, a thin plate of bone only there intervening. Of course the olfactory tracts and bulbs, so little developed in man, correspond with the ethmoid, and the grey perforated space of the brain behind corresponds to the body of the sphenoid; the cerebellum is covered by no portion of the parietal, but only by the mastoid portion of the temporal and the occipital.

The Sylvian fissure is the principal inlet by which the outer convex surface of the brain receives its arteries, and it is by its being little or

strongly marked a measure of the straight antero-posterior direction of the convolutions, or of their being more or less arched and doubled upon themselves. Foville describes the fibres from the spinal cord and crus as directed by, or following in some measure, the direction of the low convolutions (operti) of the insula situated within the fissure, and, in a fan-like fashion, forming its marginal convolutions on the one hand, being in themselves one perfect system not to be divided, and on the other, constituting a second inner set of convolutions circling the great longitudinal margin of the brain. According to this view convolutions on the exterior of the brain are arranged in two circles, or parts of circles, and with a third internal one to be described, all terminating and connected about the locus perforatus or anterior centre of the inner ganglionic matter of the brain. The third circle is the gyrus fornicatus, continued in a clasping fashion all around the corpus callosum, and of the same medullary appearance, and then along the inner margin of the tempero-sphenoidal lobe as the hippocampal, and finally the uncinate convolution; having behind a connection with the occipital part of the brain, and indeed excentrically with all the other convolutions; it also surrounds the peduncle of the brain, and its two extemities merge between the point of the temporal lobe and the external gyrus belonging to the frontals, with the locus perforatus, and notably with the point of origin of the convolutions of the island of Reil, as well as with the hippocampus, analogous indeed to the arrangement of the two preceding circles. Without this, on the inner suface of the temporal lobe, are gyri, lingualis, and fusiformis, having relation to the descending cornu, separated by the collateral fissure. On the outer surface of the brain are many important gyri and sulci—the frontal bounded in the way described—ascending parietal, separated by the fissure of Rolando; other parietal gyri above the extremity of the Sylvian fissure, called the supramarginal and angular convolutions, also the posterior parietal, continuous with the præcuneus internally, and having externally the interparietal fissure. There are three parallel gyri running along the temporal lobes, and lastly, supra-orbital convolutions, which, however, will not be dwelt upon here. The uncinate fasciculi form a notable connection between the frontal and temporal lobes.

Professor Turner points out that the parietal prominence corresponds pretty commonly to the supra-marginal gyrus; and further, that some latitude must be allowed in describing the lambdoidal and squamous sutures as corresponding exactly with the parieto-occipital and Sylvian fissures.

There seems a somewhat analogous communication between the parietal and occipital gyri behind, as is described between the parietal and frontal before; but the occipital lobe is commonly more precisely marked off, the communicating or annectent gyri in the quadrumana are more or less covered from view. In these last animals the posterior lobe is ample, and such seems a quadrumanous rather than a human character. Yet in man, though it is smaller relatively, it has a more convoluted surface; and gyri, which can only be reckoned as annectent or occipito-parietal bridges, form a considerable

portion of the parietal part of the brain. As to the above peculiarity the question arises—What is the relation of the extra development?

How far the external divisions, and, moreover, the lobules and gyri are of significance, that is, how far they correspond to internal structure, and are appropriated exclusively to particular functions, is a serious question in every sense. Turner's description of the convolutions, as well as that of Ecker, are valuable as a kind of first survey of a region more intimately to be investigated, though Meynert speaks lightly of such arrangements—advocating a longitudinal though a somewhat interrupted one. A scientific arrangement should show us the connections of the convolutions with the ganglionic centres and the fasciæ of the crus; this task, attempted by Foville, has been especially undertaken by Mr Swan, whose dissections at anyrate speak for themselves in the College of Surgeons, as do the engravings of his later work, though the descriptions are as usual with him very obscure.[1] He appropriates the region lying upon each side of the longitudinal fissure (so far as extend according to his idea the diverging fibres of the corpus callosum, and which receives no fasciæ from the crus) to the mental faculties; but its posterior portions, and indeed those of the whole brain, appertain to sensation. Consequently, to this, the corpus callosum is not a general commissure, but belongs only to the medial part of the brain; herein Mr Swan agrees in some measure with Foville, who makes it to be continuous only with the formative fibres ascending from the crura; more laterally external to this median region exists another equally longitudinal, the intercedent region appertaining in front to smell, further back mostly to the cranial and spinal motor nerves, then to sight, and finally behind, at the very summit of the cerebrum, constituting the cerebral representative of involuntary or respiratory power, so far as we suppose it has a cerebral representative. The involuntary convolutions at the summit of the brain is represented by the club-shaped mass seen in a longitudinal section of the medulla oblongata; above, in its passage upwards, this seems especially related to the grey matter within the third ventricle, the tract ascending through a kind of ring in the thalamus. The further continuation backwards of the region becomes, like the previous median region, sensory. As the eye, face, head, &c., are supplied with other nerves, according to Swan, the motor tracts from this region might perhaps have been considered by him involuntary, or may be of passion, or emotion. Another region, external motor, appropriates the remainder of the convex surface of the brain, subdivided into three other layers, of which that one nearest the longitudinal sulcus appertains mostly to the flexors, and also to the muscles of inspiration; that one occupying the margin, the extensors and expiration, whilst an intermediate layer gives a second set of motor nerve-fibres, as mentioned above, to the eyes, face, tongue, neck, &c. Of these three layers also, he considers the posterior parts to be sensory. With this location of sensation in the posterior portion of the cerebrum, and its connection with the thalamus, more especially

[1] Plates of the brain, 1858.

united as the last is with the same function, many physiologists will concur.

With respect more especially to the continuation of the above tracts from the cerebral surface through the crus, a little more must be said; and in this, perhaps, his industry and anatomical skill serve him in better stead than his great suppositions apparent in the last paragraph. Between the olfactory convolution, situated in the front of the second or intercedent region, and the optic much further back, beginning from behind, we may particularise a surface descending hence by its tract to the first or front segment of the crus, and to the third, oculomotor nerve; from the succeeding surface nervous tracts descend for both the upper and lower extremities through the second, third and fourth segments of the crus; then the centre for the face, mouth, tongue, &c. sends a tract descending through the fifth segment of the crus and posterior layer of the pons, agreeing in this more or less with the nature and origin of the corresponding nerves themselves. The most anterior tracts of the intercedent region of the brain diverge outwards towards the most posterior tracts of the crusta, while the gyrus just mentioned in front of, and in connection with, the visual, has been understood to send forward its tract to give off the third nerve in front of the crus.

But these last parts, the face, &c., are, as observed before, also provided by purely voluntary motor nerves derived from tracts in a different part of the brain-surface, though the two strands coalesce in the crus. The centre for these is more at the antero-exterior part of the hemisphere, but intermediate between the extensor and flexor series of gyri; the corresponding nerves are for muscles having no antagonists, and either attached or inserted into fixed bones. These strands have already been mentioned as united to those from the intercedent region, the same applies in the case of the third nerve. The strands also descending from the last intercedent region, and going to the extremities, are united to the strands of the more voluntary flexor (inner), and extensor (outer) centres, from the outer margin of the brain.

Among the inner flexor foci is one governing to a certain extent inspiration, situated, however, more forwards than its antagonist, among the outer extensor foci, governing expiration; but both their pedicles descend together towards the restiform columns, and consequently towards the grey respiratory foci of the medulla oblongata, the ratio of this being ostensible enough.

Then, with regard to the flexor and extensor convolutions for the extremities, an inner and outer series, the upper extremities have their united efferent band, joined also by the corresponding band from the intercedent region, forming the fourth segment of the crus outside of the anterior pyramid. Next, with respect to the lower extremities, the combined efferent extensor and flexor strands, together with the corresponding intercedent one, form the third segment of the crus, and the middle part of the anterior pyramid; the strands to the lower extremities and spine are also connected with what Swan terms the extensor and flexor crescentic belts. These belts appear to answer to what has been termed by others the ansa or substantia perforata.

At the posterior extremity of the outer portion of the brain are the two last foci (flexor and extensor) of the spine, and it is these two portions of the layers that form respectively the flexor and the extensor crescentic belt; the former in front, circling also the anterior commissure, and forming the second segment of the crus tending to the fissure of the spinal cord, being joined also by the extensor belt. More precisely the penultimate flexor focus forms a larger portion, the ultimate a smaller one, of the flexor belt, passing with the extensor, as just said, to the second segment of the crus.

How far does the above rather complicated account correspond to nature? Swan comes to the conclusion that the motor convolutions send down their efferent strands uninterruptedly through the internal and external striated bodies to the spinal cord, which is not generally admitted. Another objection, we think, is stronger, that the convolutions towards the external margin of the brain must have some relation to, and morphological modification by, the island of Reil, yet he makes no account of it as so modifying them; indeed, it is impossible to localise most of his convolutionary foci, well as the artist has delineated his dissections. The arrangement may be nearer to the truth as regards the ruminants and pachydermata, whose brains are included in Mr Swan's dissections, brains in which the convolutions have a more precisely longitudinal arrangement than in man, with little reflection on themselves, and with the Sylvian fissure and island of Reil scarcely indicated. The reverse takes place in man, these longitudinal convolutions being probably infringed upon before and behind by other lobules, the frontal and occipital. From this consideration the parietal convolutions arising from above the fissure may be supposed to be continuous with those below, or the temporal.

It may be thought that more attention is here bestowed on Mr Swan's book than it is entitled to, yet it probably will be found to be by no means devoid of truth, nor altogether at variance with modern *localisations*.

In estimating, or endeavouring to estimate, the relative development of the brain and its physiological and physical functions, the comparative size of the organ may be considered, modified, as it is, according to age, sex, race, or by congenital disease, and we may ascertain this variation by weighing the brain itself *post-mortem*, or by measurement of the skull in its diameter or capacity. But what would probably throw more light on our problem would be, as Huschke has particularly set himself to do, to ascertain by direct cerebral weighing or measurement, or by a comparison of the capacity of the regions of the skull, the relative development of the different lobes of the brain in the above conditions, age, sex, &c.

It was shown by Wagner, as by others since, that the brain and cranium will be large in an individual of large build. The Chinese giant "Ching," not many years since exhibited, had a head too large for any European's hat to fit; but this increased size mostly depends on the mere carpentry of the skull, and fortunately does not apply to simply *tall* persons, for here a heavy cranium would be out of place, and probably in them a small cranium, or a long or high narrow one

is generally seen. Andamanese, Bushmen, and Veddahs, are small in stature, yet have a small head; whilst the little Laps and Eskimaux have a large one, it has been thought, from a morbid state. All these out-driven races seem somewhat undeveloped or degenerated. The brain is commonly the largest at from thirty to forty years of age, but it may increase even after that age, and it has been said especially in negroes. It is often large at seven or eight years of age, probably from a semi-morbid state. The frontal tuberosities are often prominent in such subjects, causing what Foville terms, the *ventricular* brain case. I have found it difficult, taking school children, especially boys, to form an opinion of their mental capacity from mere craniometry. At birth the human brain may be from one-third to one-fourth its full size, or more; 13 or 14 oz. in weight. As compared with the body, it grows very rapidly the first year or two, but afterwards the latter surpasses it in this respect. It by no means wastes *pari passu* with the body, as seen in disease as phthisis.[1] A very emaciated child of six months of age, weighing but 6 lbs. within a small fraction, had a brain weighing 1 lb. within an equally trifling fraction. In old age the brain decreases, and corresponding compensation of the size of the skull is probably made by the increase of the ventricular fluid, the thickening of the skull, the sinking of the parietal bones, and perhaps by the increased size of the glandulæ Pacchioni.[2] A large brain in adults would appear, from Wagner's tables, to conduce to longevity. As might be supposed, the brains of idiots are often much smaller than the average, whilst the average is exceeded in the cleverest men—thus the brains of both Byron and Cuvier were in great excess.

The European man is considered to have a broader, higher, and more prominent os frontis than the other sex, though with regard to the two last particulars (that is, comparatively), this may be doubted. Man has, however, without a doubt, a larger frontal superficies. In woman the parietal bones are somewhat of the child's type, and predominate when compared with the others; the skull, upon the whole, is more lozenge-shaped. Some women, however, have not a parietal projection, but their skull is round or oval. Woman's occipital region, and especially the occipital squamous process, called also the interparietal bone, are full but smooth. The squamous portion of the temporal bone is small in woman; this is not the case with the alæ majores of the sphenoid, which are large. In the negro, &c., the alæ do not always articulate with the parietals, but are cut off by the junction of the frontal with the temporal, or by intercalated plates of bone. The ascending convolutions of the female brain are less inclined, the central fork more anterior, the frontal lobes shorter, and the corpus callosum corresponding. The hinder convolutions are more developed, also the thalami predominate in her; but in man the corpora striata

[1] In one instance of this disease there appeared to be atrophy of the convolutions confined to the temporal lobes.

[2] In an old woman upwards of ninety years old the brain was very healthy, but the sulci between the convolutions were generally enlarged, with much effusion under the arachnoid. The dura mater was opaque and like parchment, and the skull very thick and spongy.

both external and internal; in her sentiment, perhaps, in him volition, being prominent.[1]

The skull of woman compared with that of man is small, small even when the comparative weight of the body is alone estimated, exclusive of sex. The average weight of brain, according to Parchappe, is 1368 grammes, or about 3 lbs. Eng. in man; 1206 grammes, about 2 lbs. 1 oz. Eng. in woman. According to Flower, man's skull cavity as to woman's is as 1000 to 856. According to Tiedemann, the average male brain is 3 lbs. 10 oz. the female, 3 lbs. 5 oz. Huschke gives for the male skull capacity 1772 grammes, about 3 lbs. 14 oz.; the female, 1590 grammes, about 3 lbs. 8 oz.; brain tissue, 1424 grammes, about 3 lbs. 2 oz. male; 1272 grammes, about 2 lbs. 13 oz. female. He says that man's skull reaches one-fifth or one-sixth greater inner capacity than woman's, others think not so much as that difference by one-half (man's brain to woman's as 10 to 9), whilst in some races the inequality between the sexes seems less; thus the European man much exceeds the corresponding female. The negro is commonly a good deal below the European man, whilst the negress not unfrequently appears to approach the European woman. According to Huschke, old women decrease in brain weight less than old men.

The above figures are perhaps somewhat unsatisfactory. The eminent surgeon Dupuytren had a brain agreeing more than that of Byron or Cuvier with the rest of his fellow men, it being 1436 grammes, or 3 lbs. 2 oz. Careful observations on the weight of the brain, distinguishing sex and nationality, and as belonging to the mentally advanced and cultivated individual, or the reverse, are still a desideratum. Errors seem to have originated from the difference of the weights adopted, and in measuring the skull capacity from the different allowances deducted for the membranes, &c., also from the material used in measuring. We have many tables drawn up in asylums, infirmaries, and workhouses. Dr Crichton-Browne's figures are—male, 1334 grammes; female, 1198 grammes. Dr Thuraum's figures are rather less. The above numbers refer to cases of all sorts, the mental disease being of a wasting nature or not, and the weights are somewhat below what ought to be called the human average. Dr Crichton-Browne says, in acute cases of mental alienation, the weight was about 6 per cent. greater, and considers that more like the average weight in sane people. Dr Boyd makes the brain of the inmates of workhouses not to weigh more than the mentally alienated, which we may believe, from the mental character of many of the inmates, as so great a cause of pauperism is mental weakness.

There being generally a relation between the brain and the skull which contains it, and besides as we must obtain from the examination of the skull alone whatever light on psychology or brain-function can be learnt from the study of the encephalon in many of the races of mankind, craniometry becomes of interest to us. Of course the brain

[1] Wagner figures a female brain in opposition to that of Fuchs of the opposite sex; the former is certainly narrow in front, and the frontal convolutions much simpler. Yet in this last respect, if he had made other comparisons, the result would have been different.

and skull vary according to race; the savage man will on the average have a small brain, the advanced man, at least if the doctrines of development in contradistinction to that of primitive distinctness of race hold good, a more amplified one and corresponding skull; more than this, the average bodily size of the races varies, and, as already said, the largest men will as a general rule, with some exceptions, have the largest brain, at least the largest skull; in almost all races, however, large skulls occur. The uncultivated portion of the Irish have less cerebral development than their more advanced countrymen who are far from deficient, often macrocephalic.[1]

Huschke found the German skull to be large. Morton also found the Teutonic cranium large, that of many Peruvians, Negroes, Hottentots, Hindoos, American Indians, and Australians, of small proportions. The smallest skull Mr Flower has found belonged to a Cingalese (Veddah). According to Dr Davis we may assign 92·1 cubic inches of skull capacity to European races, 89·7 to the Oceanic races, 88·7 to the Asiatic races, 86·2 to the African races, 81·7 to the Australians, 87·5 to the American races. It is believed, though not quite proved, that the Chinese come below the European (*Brit. Med. Journal*, May 31, 1879.) The skull of the lower races is sometimes rather thick and heavy than capacious. Dr Davis in his *Thesaurus* gave the mean cubic capacity of the English skull as only 90·9, but thinks that size too small, many of his English skulls having been collected for phrenological purposes. According to Meigs the English skull has the large cubic capacity of 96, representing a nett weight of brain of about 3 lbs. 11 oz. Size of brain, however, scarcely appears to be altogether either a national or a race character, but liable to vary both from the organisation and habits of the individual.[2] The modern English skull, according to Davis, has a circumference measuring 20·1 inches; anterior posterior, diameter 7·2 in.; transverse, diameter 5·6 in.; proportion of breadth to length, 78. The corresponding amount obtained by measuring the heads of four Welshmen from a remote village in Caernarvonshire I found to be 21·9 inches in circumference; anterior posterior, 7·2; transverse, 5·4; breadth to length, 80.

As already observed, it would be more interesting could we exactly estimate the relative size of the different cerebral lobes, ascertained either by measurement or weight of the brain itself, or measurement of its bony case.

The following deductions are principally from Huschke, who appears to have paid most attention to this point.

[1] Whilst the Peruvians are well known to have a small capacity Mr Flower gives a very large one to the less civilized Chinooks, who, however, if we may judge by their productions, are not deficient in aptitude. The Kaffirs, too, have a skull of large capacity. In a Negro of the more advanced type, though the skull was narrow and thick, but elevated, the brain was developed to the British average, and weighed 49 oz.

[2] After all it must be conceded that in estimating brain capacity richness of the convolutions and of their grey cortex takes precedence over mere size. This may be seen by an inspection of Wagner's Plates, as in the figure of the brain of the celebrated Gauss, less in size but much richer than the brains of other known individuals that he figures,—than that of Dirichlet for instance.

The frontal and interparietal regions are the parts of the skull having the greatest post-natal expansion comparatively, the first trebling its superficies during childhood and manhood. The parietals attain their full size earlier. Europeans have, as a rule, skulls which are not less in length from the forehead to the occipital tuberosity than 7 inches, but a few Europeans, where height of skull more predominates, as Finns and Turks, as well as many Asiatics, and Eastern Islanders where both height and breadth preponderate, do not attain that length. Length (dolicocephalism) is more especially characteristic of Africans (and Papuans), though not absolutely, but on comparing length with breadth, for in them it scarcely exceeds the length of even some European females, owing to the generally greater size of the European skull. Sometimes the skull, and consequently its contents, undergoes an elongation either from artificial moulding or an unusual closing or synostotis of the sutures. Such a deformation would mathematically lessen capacity, unless compensated for by some expansion elsewhere, but it is doubtful what is the exact effect on the physique and morale of the brain, though probably it is a perversion. The modern European and Caucasian skull exceeds in breadth (brachycephalic) and especially in frontal breadth. Some Oceanic races, and some American Indians also, are brachycephalic. Parietal breadth is less perhaps an Asiatic characteristic than frontal, whilst, as observed before, narrowness of skull is an African, or rather Negro, Australian, and Andamanese trait. The transverse diameter, however, may preponderate, and *vice versa*, even in the same families—nay, of twins one may present brachycephalic and the other dolicocephalic characters.

But taking the comparative development of the different regions of the skull into consideration, we might also seek for conclusions by measuring the longitudinal arch of the skull, from the root of the nose to the posterior margin of the occipital foramen, and compare the frontal, parietal, interparietal, and occipital portions of the line with each other, or with a line taken over the arch transversely. The frontal portion of the longitudinal arched line will appear, when compared with the parietal, long in many females; this is generally a perfection, but it extends a good way back without being really longer in many Africans, and the internal cavity formed in such skulls is shallow, and therefore the Negro's frontal lobes are sometimes poor in this respect and at the sides; the reverse is a European characteristic, mere height, however (unless it is frontal), is not altogether European but rather Asiatic, and it is seen in the Eskimaux and Siamese.[1] The parietal line must be short where the frontal predominates; the occipital portion of the same longitudinal arched line is short in the lower races, either from an excess of the parietal portion or from a backward position of the occipital foramen. With respect to the occipital transverse diameter between the most remote points of the lamdoidal suture it is least exceeded by the transverse line between the parietal prominences in the narrow skull of the male African; females have in

[1] Professor Flower has lately ascertained that some Fijian skulls are the longest and narrowest of any known.—*Nature*, July 8, 1880.

some races a parietal excess. The parietal breadth also predominates over the occipital progressively in Asiatics, Eskimaux, Europeans, Australians, and Oceanic races. The Eskimaux. however, have *in toto* very narrow though very high skulls. The European exceeds the African in all the above measures as follows:—frontal by $\frac{3}{10}$ of an inch, parietal by $\frac{6}{10}$, occipital, $\frac{2\frac{1}{2}}{10}$ths.

The cerebellum, both in man and animals, is very small at birth—from one-sixth to one-eleventh of the weight of the cerebrum; it increases much at an early age, becoming seven or eight times the size it was at birth. At birth I found it in one case only one-twentieth of the weight of the whole brain. It has been found large in many criminals and lunatics; castration appears to prevent its full development, and this seems more determined by the muscular growth of the body. Huschke makes it at birth as 6½ to 93½, at walking time, 13½ to 86½. The cerebellum, as a whole, decreases less than the cerebrum in old age; however, its vermiform process is considered to be prominent in middle life, and in the female, whose cerebellum is fairly developed, but with no excess as Gall supposed. The cerebellum is long in the Negro as is the skull, but probably *in toto* smaller than in the European. It is said to be well developed in the French, corresponding to their natural grace and dexterity; in fact, comparatively better developed than is the cerebrum.

It varies much in man, and scarcely appears to have any purely intellectual significance; the accompanying cerebrum it is said may be small when itself is large, yet it decidedly militates against these views, that when either cerebral lobe is wasted the opposite cerebellar lobe is so likewise.

We observed at the commencement of this paper that light may possibly be thrown on the physiology of the nervous system by a study of it as it gradually developes itself, or rather as it is found developed in the different groups of animals, beginning at the lowest and ascending to the highest. Nerves render impressions made in a a distant part to a common centre, as in ordinary sensation; or connect these sensations with a distant part to produce muscular action, as in sneezing; or convey the impetus for motion from the centre to the circumference, as in common voluntary movements; or connect two motile parts in unison, as the external and internal respiratory muscles; or intimate to one part the organic state of another, as takes place between the stomach and the heart. Besides nerves or nerve fibres we have also nerve cells, the especial quality of which is an advance on that which every cell of the body has, capability of impression culminating in a cerebral cell in sensation and motility; the corresponding quality of the nerve fibre is conductibility, more elaborated and more capable of isolation than is any other similar conductor. Motion is a function of muscle, not of nerve. Perhaps nerve granules are another important constituent of the nervous system.[1]

[1] In an address by F. M. Balfour, F.R.S., delivered in Section D. of the British Association, 1880, is an interesting resumé of what has been done in this subject by Von Baer, Romanes, the Brothers Hertwig, &c.

It does not appear that a nervous system, including both nerves and ganglia, is requisite to animals for them to perform any of their functions in the simplest form, feeling, motility, or nutrition; at least, we see no proof of its existence in such cases any more than in a portion of protoplasm, of contractile fibre, or in a cell. Neither ganglia nor nerves are clearly seen in the irritable actinia, though certainly the nature of its tissues is such as must render their demonstration difficult, and so in the asterias or star-fish. The former, when we irritate a single tentacle, gradually draws them all in one after the other, but irritated at the sessile-disk draws in all of them at once, and this certainly answers to Spix's account of the basal ganglia and communicating nerves. The common actinia has also ocelli-like organs in a row around the mouth. In the star-fish, as in the acephala, nerves with sense organs, visual or auditory, are now generally admitted. In other animals the nervous system may consist of little more than an internuncial or combining single cord, as in a sipunculus, or of a single ganglion between the orifices of an ascidia as it appears to us.

In higher animals the varied organs must be connected by nerves. There must be a sensorium commune, and this must be united with the ganglia whence motile impetus proceeds, necessitating a combination of nerve cells and of commissural connections, also constituting the centre of the animal's individuality. But a separated muscle contracts when irritated by simply pricking its fibres, whilst on the other hand, a worm moves and writhes when divided, but it is only the front half containing the cephalic ganglia that progresses.[1] In the last case we see the start of that development through which the encephalon becomes the seat of intelligence, the brain the organ of mind, or in other words the medium through which the exterior world acts by means of sensation on the animal, and the animal by motor impulse on the exterior. The brain and nerves, as a whole, present in all animals a resemblance of the whole form, as indeed may be said of the vascular system or of the skeleton; but in the nervous system, its functions being higher, individuality more especially lies. In articulated animals each ring of the body is more or less the copy of the other, and so with the ganglia and nerves, those of the head, however, being the ganglia to which the special nerves are mostly directed, whilst the following are either incited from it through the longitudinal cords, or are excito-motor with a double set of nerves to correspond, and others differently disposed to regulate the rhythmical movements of one articulation with another. Throughout molluscous animals ganglia of threefold nature are developed, sensitive, motor, and respiratory, and in addition others regulating organic or nutritive life; for the molluscous nerves and ganglia by no means correspond in the whole with the ganglionic nerves of organic life in higher animals. The molluscous nervous system corresponds, though widely different in arrangement, to the cerebro-spinal, and both have an appended organic nervous system.

[1] This agrees with Mr Wood's examination of the functions of the nervous system in the cray-fish.

The higher mollusca have a cerebrum above the mouth, and the ganglia below it still in connection with the mouth answer to the medulla, though very different in localisation, owing to the different situation of the locomotive system, and to its conforming to the molluscan characteristic, the annular arrangement of the ganglia around the mouth, the morphology widely differing from the vertebrate, and, therefore, the disposition of the nervous system. In the cuttle-fish (*Sepia*) the cephalic ganglion at the upper part receives olfactory and optic tracts from olfactory and optic lobes; the lower part gives off nerves to the locomotive arms at the front, and has also tracts from the olfactory or gustatory ganglia, and from the upper cerebral; the back portion also gives off motile nerves, but they are all connected with swimming, which is intimately in unison with respiration; it is also connected with the auditory sacs, as the functions are in the nervous system of higher animals. From the very posterior extremity long gangliated visceral and branchial vagi nerves are given off, also two columns analogous to a spinal cord, one portion purely motor to the side fin, the other with a stellate ganglion giving off nerves to the more sensitive sac. These two latter nerves are intimately connected with fine visceral nerves, the centre of which is a large gastric ganglion, and one, two, or more small ganglia near the commencement of the œsophagus.

The fish, especially adapted by its form, its large but simple mass of muscle, and its swimming bladder, to progress and float in the water, needs no large brain to animate its organs, acting as its nervous system does in an automatic or reflex manner, guided however by the cerebral nerves of sensation. Hence the diminutive size of the brain and cerebellum, appearing to be little more than a continuance of the spinal cord. In the osseous fishes, of which the cod is a good instance, the front ganglia may be called the hemispheres analogous with the olfactory portion of the mammalian cerebrum; however, in front of these are the true olfactory bulbs often at a considerable advance, connected by an olfactory tract, at other times sessile. Further back are the optic lobes, hollow within, and presenting on the floor certain elevations likened by Fritsch to the corpora quadrigemina; there are also appearances of thalami if not of corpora striata, and indeed these parts seem homologous with the ganglia mentioned, roofed in by a portion of the basal mammalian brain. An opening in the floor of the cavity leads down to the pituitary body, and backwards to a fourth ventricle, and the fourth nerve arises behind, sufficiently showing what these ganglia are, though the hemispheres are not consolidated with them. Behind we see a simple tongue-shaped cerebellum, without side processes, in the cod, but in other species, where locomotive, or respiratory, or electrical organs are more developed, garnished with sides lobules, as in rays, sharks, &c. Generally spinal impetus suffices for locomotion, olfactory, optic, or acoustic sensations, guiding—the cerebellum directing the different systems of muscles as far as they require it, be they respiratory or locomotive, and most in the skate and shark.

The skate and shark have no swimming bladder, hence their large

brain and cerebellum are more in requisition perhaps for swimming than in most fishes; there is a commissure also between the right and left trigemini and facial nerves, also supplementary gyri at the side of the fourth ventricle, belonging perhaps to the trigemini.

In the reptiles there is not the above incertitude respecting the parts of the between- or mid- brain; there is great ascent of general development, and distinct hemispheres with striated bodies. Remarkable upon the whole for their sluggish or simple movements, they are nevertheless like the fish (at least the lowest reptiles, the batrachia), independent of the cerebrum, for motor impetus, powerful as that is; neither is the cerebellum much developed, and their movements upon the whole require little separating or inhibitory action. The movements of the frog are remarkably combined, it leaps and swims, but does not walk as the toad, with its larger cerebellum; in the frog it is but a commissure, its spinal cord thick and long, with a ventricle all down, whilst in the toad the spinal cord is shorter. The frog leaps or swims when the cerebrum is removed. In the higher orders there may be more cerebral action, and both cerebrum and cerebellum are more developed, yet even in these their sluggish and statue-like position is very remarkable, though at times they are more active.

Leaving these cold-blooded and slow respiring creatures, we have a much larger development and importance of the nervous system in birds, though upon decapitation they appear for a short time to flap their wings consentaneously, but unlike the frog can accomplish no regular locomotive action, though if the cerebral lobes simply are removed they can.

The bird has a large brain as we might suppose from its diversified faculties, the seat of volition and of sensory perception, but, however, with less of the tactile, for the latter must be small in the bird; the corpora striata (motor) are amply developed, the thalami (sensory) less so. The impulse for flying seems to descend through the spinal-cord, the cerebellum exerting but a combining action, the wings generally in unison. The legs seem more automatic, and this dependent on spinal reflex action; the cord supplying the legs has the corpus rhomboidum, a superadded ventricle with grey ganglionic matter. The bird rests or sleeps standing on its legs, or even on one, the feet also the only part of the body free from feathers and adapted for bodily sensation. The cerebellum is primarily developed in its central portion (vermiform process), indicating that its action is on the mid-trunk where the great muscles moving the limbs originate; whereas, perhaps, where side lobes are developed we may appropriate these to limbs. Some birds progress by hopping, others by true walking, and the cerebellum is probably modified accordingly as to its side lobes; in the Mammalia a similar principle may exist, both the middle and side lobes of the cerebellum being regular or irregular as the locomotion is uniform or not so. The optic lobes or bigemini (answering to the corpora quadrigemini) are placed fowards and not behind the cerebrum, corresponding apparently to the almost absence of thalami. The olfactory lobe is not much developed, smell being a weaker guide to birds than sight. The corpus callosum is not developed, and the

cerebral lobes are consequently not united though in apposition; the anterior commissure is present; the intraventricular parts, except the corpus striatum, less defined.

Amongst the Mammalia, the monotremata as well as the marsupialia, are peculiar in their brain, as well as in other organs, showing a great difference between them and other Mammalia, difficult to explain, except from their being of a different epoch as to their appearance, constituting a distinct mammalian kingdom rather than an order. The great commissure (the corpus callosum) is very small, and the third ventricle situated between the thalami comes into view when the hemispheres are drawn aside, roofed in, however, by the fornix. This, connected in front with the parts at the inner origin of the olfactory nerve, diverges backwards and downwards, and so to the hippocampal and vast olfactory tract, forming the frame of the hilum where the crus enters. The brain, especially in the echidna must be an olfactory organ *par excellence.* In both the echidna and the ornithorynchus the frontal portion of the cerebrum is small, the bulk being the parietal portion probably sentient; yet the muscular strength of the former species is said to be enormous when dug out of its retreat.

It is curious that whilst the ornithorynchus has the cerebrum smooth like that of a bird, the echidna has many transverse deep sulci behind, a difference not generally seen in species of the same order, therefore the two animals have more than generic difference. The spinal cord is massive, giving auto-motive power, regulated however by an equally developed cerebellum, which has in the ornithorynchus side flocks lodged in cavities of the temporal bone. We may conclude that both animals are somewhat stupid not over active, sensori- rather than ideo- motor; the olfactory and tactile organs, and especially the fifth nerve amply developed, the posterior corpora quadrigemina small. In other Australian animals, as the kangaroo, the anterior part of the brain is very narrow, the hind part broad. In numerous Mammalia (the lissencephala of Owen) the brain is devoid of convolutions, so that there is nothing except comparison of size in fore and aft brain to enable us to draw any conclusion as to the function of the main regions of the brain—that is as to the seat or situation. As a rule sulci are not necessary to shelter the small vessels of small brains, and consequently they have them not. Yet, if the small animal belong to a class, the brain character of which is to be convoluted, it in this case will probably conform to the family type. Large brains must have a better mechanical provision for the distribution of the arteries, but the arrangement depends for its *raison d'être* not entirely in the vascular distribution itself, but in the physiological morphology of the organ.

With respect to the small smooth-brained animals, they are often not wanting in intelligence. For instance, the squirrel is very observant and quick in its movements, with the faculty of construction, and foresight of hoarding, and using its fore-feet as hands; still more, with respect to other Rodents and Insectivora. A difference may be seen in them in the shape of the brain; for intance, when we compare the broad fronted cerebrum of the constructive beaver with the same part

so narrow in front in the rabbit. These brains differ in the comparative development of the nervous centres of smell.

The volant bats have a small cerebrum, but a comparatively large cerebellum. The timid hare has a portion of the cerebellum surrounded by the semicircular canals—a provision probably frequent in timid animals. The mole has the organ of sight very imperfect; the eye is a light—not an object-organ, with little trace of optic nerve or tract and ill-developed inferior corpora quadrigemina. Its olfactory and auditory nerves are on the contrary highly developed, as are the hippocampi.[1] Prof. Turner describes the brain of an armadillo (exemplary of the Edentata) as not devoid of sulci, at least sufficient to mark out into three divisions the cerebrum—the anterior being the olfactory bulbs, with their large tracks running backwards—behind this in front and at the sides a gross portion also running to the posterior of the brain, and forming with the preceding track the temporal lobe, whilst above and behind is a superincumbent portion, being in shape as it were an epitome of the cerebrum itself; the corpus callosum is not much developed (*Journ. of Anat. and Phys.* 1867).

Some difficulty is experienced in comparing the lobes and convolutions of the brain of the remaining Mammalia, and especially with that of man. It may be premised that some similitude exists between the arrangement of the cerebrum with that of the spinal cord—that a cross section of both presents parts of somewhat the same import, and relatively similarly situated. In a section of the cord we have a central cavity, more or less obliterated however—an anterior motor strand with anterior grey cornua, represented in the brain by the crus and the corpora striata, lateral or middle strands traced by Swan upwards to the vertex of the brain, and posterior sensory tracts having in the cord the posterior cornua and substantia gelatinosa represented in the cerebrum by the strands more especially connected with the thalami, and going to the posterior part of the cerebrum, or rather the middle and the outside of the hinder half.

An anterior cerebral region we have apparently in all Mammalia, embracing perhaps gyri which appertain to intelligence and volition, and which are connected with the gyri initiatory of movement and probably especially with the movements of the hand and anterior extremities. There is reason to believe in the existence of a cerebral focus of respiratory action in the mid-brain, but more especially of sensation—the tegmentum of the medulla expands into the thalami in all these animals, and so into parietal and temporal lobes, but in the primates there is a distinct hinder portion or occipital lobe—large in quadrumana but less convoluted than in man — and this lobe appears ill marked in other Mammalia. In accordance with our suppositions this lobe may probably have relation to the hind rather than

[1] In the *Zoological Transactions* are the accounts of the examination of the brain of several rare animals, as the manatee, rhinoceros, hippopotamus, hunting dog, &c., by the late Dr Garrod. Professor Flower has given the description of the bush dog, which appears somewhat transitional between that of the *Canidæ* and the *Felidæ*.

the front of the body, also more especially to sensation; thus it is seen principally in animals with hind hands and prehensile tails, and in man, where the hind extremities can in no wise be compared to the little sensitive clawed or hoofed hind legs of Carnivora or Herbivora. Dr Ferrier's experiments, however, do not agree with these views.

This occipital lobe is scarcely seen in the last orders mentioned, though certain outputs of the posterior convolutions may be considered as incipient occipital lobes; such are the internal longitudinal convolutions lying on the falx of Ruminants, brought apparently by a species of supination to the exterior, towards the back part of the cerebrum, and often corresponding to the lengthened portion of the occipital bone, called the interparietal or supra-occipital.

In the Ruminants (ox or sheep) and Solipedes (horse) we find the brain large and convoluted, agreeing with the size of the body, the convolutions longitudinal in their arrangement, without being much bent round the island of Reil. A crucial line above, over the inner edge of both hemispheres, is traceable downwards to the calloso-marginal sulcus, and seems to show where the anterior lobes end, marking a good sized frontal lobule, the line answering, I think, not to the fissure of Rolando, but rather to the præcentral ascending oblique fissure of man, found, however, not behind, but before the coronal suture, which is far back in horned animals. Another matter besides degree of intelligence should perhaps be here borne in mind, the development of the frontal bone from the presence of the horns, which may account in some measure for the stupid sheep equalling the sagacious dog in size of anterior lobe, but here again we must allow for the difference of the mode of life and amount of education. The olfactory tract is greatly developed, but the temporo-sphenoidal prominence is small.

There are three long parietal convolutions on each side in Ruminants, besides the superior convolutions supposed to represent the occipito-parietal. In front the division of the longitudinal convolutions is less distinct; they are here gathered into one set on each side—the olfactory and orbital portion. The sheep may be said to have two double parietal convolutions on each side, and one internal (occipital), the latter terminating in front at the crucial or rather V-shaped descending sulcus, the parietals run into a mass of frontal and supra-orbital gyri. Below is a lower parietal or Sylvian convolution, and the hippocampal eminence runs up behind into the crested convolution, and into that which we suppose to be occipital.

Supplementary to the last brains may be classed those of the Cetacea—large and much convoluted; the disposition of the convolutions more or less longitudinal; the large brain development somewhat accounted for, as the brain tissue is of a light and perhaps coarse development, as we see in the bones of the animals: the same hydrostatic principle evident in the head of the spermaceti whale.[1] The

[1] The brain of the white whale is well figured in the *Journ. of Anat. and Phys.* 1879, by H. C. Major. The sulci in the Ungulata have been systematically described by Krueg (*Nature*, 1878). Mr Galton has described the brain of the manatee, Sumatran rhinoceros, and several other interesting animals.

olfactory nerves so highly developed in Ruminants, are actually absent in most Cetacea, other nerves, as the fifth, seventh, and eighth, supplying those parts for respiratory purposes which in most Mammalia are partly subservient to smell.

The parietal bones in the Cetacea do not meet in the middle line of the skull above, and the convolutions here seem rather to correspond to the parieto-occipital than to parietal.

The brain of the Ruminant does not differ very much from that of the boar, which may be said to have two double, or four single side convolutions passing from before to behind, with the Sylvian fissure more evident. The olfactory portion is well marked, inserted between the anterior lobules. The upper convolution sends a process downwards into the longitudinal fissure, behind the crucial or V-shaped sulcus, and further back a process reflected into the parieto-occipital; the lower convolution bends around the fissure of Sylvius.

The remarkable antero-posterior direction of convolutions which we see in Ruminants (though the posterior parietal extremities have a tendency to diverge, apparently to form posterior or parieto-occipital lobes) no longer exists in the Carnivora—at least, though the parietal convolutions may be straight, still their extremities bend round an introcedent Sylvian fissure. This is well seen in the dog, the wolf, or the bear; in this the carnivorous animal resembles man, in whom the brain is also bent on itself as it were. These convolutions may be said to be about four in number, with a tendency to divide behind, and so form the occipito-parietal lobe, ill-developed however, as is the supra-occipital bone above.

In front the upper convolution bends around the anterior (olfactory) gyri, marked off by the crucial fissure from the rest of the frontal and orbital lobes, having more of the cerebrum before it in the dog than in the cat or even the fox, the cat's brain looking as it were cut off before, the fox's sharp, the dog's broader. In the latter, four arched supra-Sylvian convolutions bend down before and behind, in front bordering the olfactory lobe, at the back forming the temporal prominence, and also by a division seeming to provide for an occipital lobule. An upper marginal tract of the longitudinal fissure seems more connected with the frontal convolutions than the curved or arched gyri. The dog's brain is not nearly so large as that of the wolf; education does not appear to have had the effect of much increasing it, that is, if we suppose it true that the dog is a reclaimed and civilised wolf. Large dogs have not a proportional enlargement of the brain, nor is that of small dogs correspondingly less. The arched convolutions may differ in proportional size according to species: the upper temporal gyrus is large in the spaniel, small in the bull-dog, its anterior bend less in the spaniel. The fissure of Sylvius is directed more backwards, and the cerebrum elongated in the greyhound, foxhound, and Newfoundland dog. The frontal lobe seems large in the spaniel, but also in the bull-dog.

In the brain of man we have a vast enlargement of the cerebral convolutions, but probably the occipital lobes are larger in the Simiæ in proportion to the size of the cerebrum, but in man much more

convoluted.[1] The anterior lobes are much expanded at the sides; a central lobule here starts from the orbital surface and runs backwards somewhat further than the coronal suture, the inner surface of the parietal bones more or less marked, as already mentioned, from the vessels which go upwards, following the sulcus, which ascends from the anterior part of the Sylvian fissure, forming the division between the frontal and parietal portion of the brain, though the præcentral sulcus further back is mostly considered to mark this boundary; the debateable land is seen above to be of the shape of a broad halberd or fleur-de-lis; at one or the other boundary is the upper end of the superior frontal convolution, and below on each side is a middle and inferior one. Behind the first oblique ascending convolution, and its anterior sulcus, bridged across by the inosculations from the frontal lobes, is a second oblique ascending parietal convolution, having before it the fissure of Rolando, and behind this there is sometimes a third similar convolution and sulcus, the latter making part of the posterior parietal sulcus. This last sulcus divides the remaining upper parietal portion of the brain into two sets of lobules, of which the inner (upper parietal lobule) is quadrilateral in form with the parieto-occipital fissure behind, and with its fellow, together with the gyrus behind the fissure of Rolando, forming a bat-shaped region in this part of the brain surface; the other set is behind the termination of the Sylvian fissure, and has been called the inferior parietal, touching upon the angular and marginal gyri of others, and here the supra-Sylvian convolutions probably are bending round the top of the Sylvian fissure, as in the carnivorous animal. Further back is the occipital lobe, more or less separated by a fissure on the outer surface, more evidently within, and this fissure is crossed by bridging connections from the parietal and temporal convolutions. Dr Foville was the first to point out the peculiarities of that great circular convolution, called limbic by Broca, otherwise the gyrus fornicatus, bordering the cerebral inlet, and surrounding the peduncle. It may be followed up from that grey commissure connected with the olfactory and optic nerves, and at the base of the brain—the locus perforatus—it mounts up along the inner surface of the hemisphere over the corpus callosum, the white internal fibres also ascending in a crested fashion—the convolution expands into the quadrangular lobule or præcuneus, corresponding pretty well to the posterior parietal lobule above—hence the limbic rim is continued downwards, and then forwards, receiving tracts, as it were, from the occipital and temporal lobes connected with the dentate lobule, hippocampus, and uncinate gyrus, and so again to the locus perforatus. This forms the great olfactory circle, and indeed the frontal lobe, in many animals, where smell is far more developed than in man. We need not enumerate the divisions in the outer or inner surface of the occipital lobe, but the longitudinal or calcarine fissure

[1] A high function is alloted to the occipital lobes by Hughlings Jackson, and other clinical observers, though Ferrier allots to them the organic and nutritive functions. The latter gentleman, however, with Prof. Yeo, now finds that upon extirpation of both occipital lobes and both angular gyri *vision* is quite destroyed.

of the last indicates the situation of the hippocampus minor in the posterior horn of the ventricle, a feature of the primates. Professor Dalton, of New York, entertains ideas similar to the author's regarding the doubling on themselves of the lateral parietal and temporal convolutions (*Brain*, July 1880). The upper temporal varies in calibre, &c.

The production of defined movements in the limbs, &c., by irritation of the surface of the brain, in opposition to the experiments of older physiologists, as well as modern, of Flourens, Magendie, Vulpian, &c., anticipated by the opinions of Hughlings Jackson, has been announced by Fritsch and Hitzig in 1870, and by Ferrier in 1873. Modern experiments of stimulating the surface of the brain by electricity, cautery, or ablation, do not militate against what we have said, at least generally speaking. The anterior parts of the hemispheres do not respond to stimulation, and we should suppose they would not do so if they are the regions, as we should opine, more intimately concerned in psychical functions. On operating on the convolutions further back various muscles are caused to act; to speak roughly, those connected with the sense of smell, with sight, with the hands or fore extremities, and with the head; further back still the muscles moving the hind legs and tail. The whole of this portion of the brain is especially connected with the corpora striata, generally believed to be of motor function. The rest of the brain is more connected with the thalami which, as generally inferred, relate to sensation. In this latter region no response, generally speaking, takes place upon stimulation, with the exception of a few spots, as the angular gyrus which seems connected with sight, the temporal infra-marginal convolution (hearing), the hippocampus (smell, taste, &c.). These last movements appear to be reflex, the parts stimulated being the termini of visual, &c., centripetal sensation, producing the corresponding movements by influencing motile centres, elsewhere situated and connected with the striate bodies and not the thalami. Neither does stimulation appear to affect the occipito-parietal lobes as motor foci. Ferrier upon the whole considers them as recipients of sensation of the visceral organs, which theory is perhaps very disputable, as may be concluded from what has already been said.

Unlike the vascular system there is little in the nervous to demonstrate the mode of mechanism by which it performs its functions—a vessel in some measure tells us what is its use by its plain disposition; a nerve or ganglion tells us nothing of the sort at any rate indubitably. The phenomena of reflex action indicated by Prochaska, and formulated by Marshall Hall, have been in more recent days elucidated in their extensive bearings. Some have supposed them to be purposive and intelligent, which kind of functions we can hardly attribute to the spinal cord.

Beginning synthetically with the spinal cord and its functions—besides conveying nervous impulse, as both motor and sensory, to and fro between the brain and the body, it has actions solely dependent on itself, reflex actions, and from the disposition of its grey matter like a cross with a surrounding circle of the spinal nerve-tissue, the longi-

tudinal tracts, internal ganglionic cells, and their communicating fibres, there appears no difficulty in understanding its various spinal reflex action without any participation of the brain. There are other nervous actions more independent of the nervous centres than even spinal reflex action: thus it is with the sympathetic nervous system of organic life, connected however with the spinal nerves, but for what purpose seems doubtful, probably to carry upwards and downwards reciprocating nervous influence; the ganglionic seats of organic life having organic motor power and being recipients of organic sensation and the cause of their reflexion, yet susceptible of stimulation or inhibition from the animal nerves of the medulla itself, as in the case of the sphincters, the uterus, the diaphragm, and muscles of respiration generally. It is worth while to consider the different degrees of voluntary impulse exercised over motor function. The actions of the uterus, bladder, bowels, and vesiculæ seminales are independent of cerebral action; yet of these the last responds in answer to special sensations; the three first organs when aided by the voluntary or semi-voluntary action of the organs themselves, but especially by the diaphragm and intercostals. These actions themselves are the subjects of sensation, not different from the ordinary as far as the cerebrum is concerned and influenced by its ordinary reflexed motor action. Swallowing is involuntary when reflex action is produced in the shape of the projected morsel. The heart's action is quite involuntary though it may be influenced by emotion, and so that of the larynx. Vomiting, sneezing, and coughing are accomplished by the aid of semi-voluntary muscles, whose action if resisted at length becomes involuntary. Hiccough, gaping, sighing, and laughing are spasmodic actions of the same class of muscles. None of these are under the control of the cerebrum, though it may influence them in some cases. Over and above these various nervous actions, dependent on the spinal cord, or at least on parts below the cerebrum, there are others which are undoubtedly more in unison with the brain, such as impressions of sight, smell, hearing, general sensation, and pain, afferent or leading up to the encephalon, and, on the other hand, movements of various kinds brought about by impressions transferred from the encephalon to the muscles. At first sight it might appear that this afferent and efferent impetus might be accomplished by very simple means, like the to and fro conductors of a galvanic apparatus, but the requirements are not so simple.

In the first place, omitting at present the subject of nervous decussation, the brain, like the other animal organs of the body, is double, yet commonly acts as one, the body duplex the mind one; each stage of the nervous system therefore is united by commissures, even the so-called cerebral nerves themselves. The nerves of sense likewise appear to communicate with different receptive regions: (1) with the higher region of intellect; (2) with the sensorium—the optic tract, for instance, is connected with grey matter at its commencement, and then proceeds to more distant ganglia; (3) it sometimes appears necessary for the good of the being that they should have a connection also with the seat of involuntary or automatic impulse. Seeing necessitates

certain muscular movements, partly voluntary and partly involuntary, but acting in curious unison as to the two eyes.

The transmission of pain upwards seems a very simple mechanism, though there is a wide divergence of opinion as to its precise route, and whether the same channel as that of the ordinary sense of touch or of heat and cold conveys it; also, as to the precise course of that sense of muscular tension and relaxation which must be necessary to guide the body in its various movements. Many of these last impressions may be carried upwards so as to form perceptions or impressions at the summit of the cerebro-spinal system, or may stop half way. Thus in a reverie we may walk, step safely, and balance our bodies without thinking that we are walking. In this case that sense of contact necessary for balancing the body, and of the muscular exertion must stop somewhere short of the sensorium, and be reflected in the nerves at lower levels than where they are influenced by the will or ideas.

Then, again, in any voluntary movement produced by contractions of a certain set of muscles it is not the mind that selects the suitable muscles, at least after the movements have become associated by repetition. It seems to will the *effort*, rather than the *mode* of action by which the effort is to be produced. There must be here, besides the unconscious experience, some physical arrangement, we suppose, of the cerebellum.

The true structure of the brain is likely to be elucidated by a study of its embryological growth, and also of that of its bony case; Messrs Huxley and Flower especially having paid attention to the latter. As regards the embryological growth of the brain, its early phases and their external appearances are well figured by Tiedemann, and more recently by Reichert; but it appears to the writer that Mr Callender has more efficiently investigated its very early stages.[1] In the new born infant the two characteristics most apparent are, I think, the comparative smallness of the cerebellum, and the want of convolutions at the front of the brain, corresponding perhaps to the little developed movements and mental faculties. Mr Callender gives to the embryonic brain in its early stage three consecutive formative vesicles, but we would rather take Professor Owen's view of there being four, rhin- pros- mes- and ep- encephalon. Upon the doctrine of the skull being in reality a series of highly developed vertebræ, their number of course must correspond, and also the cranial nerves ought to be in accordance, though this latter point seems rather a difficult subject. Excluding the nerves of special sense, we would divide the first branch of the fifth into a nasal and ocular division, making with its second branch three nerves of ordinary sensation, while its third branch is a mixed nerve, sensational and motor. The deficient motor power in the upper branches of the fifth, is with respect to the eye supplied by the fourth nerve, apparently especially allied with expression, &c., and the third and sixth pairs, of which those, given off above the cerebellum, appear not to be subject to its functions of controlling, inhibitory, separating,

[1] Lectures in *British Medical Journal*, 1874.

&c.; the seventh nerve, most conveniently from its course, supplies motor power to the parts of the head and face, as regards which the fifth nerve is deficient. We omit the respiratory nerves, peculiar, like the nerves of sense in many respects. Mr Callender, in his accounts of the brain of the very early embryo, takes two parts, the pituitary body and the pineal body, one fixed at the anterior termination of the notochord, and the other at the internal tuberosity of the occipital bone, and compares them with the structures at the lower termination of the spinal cord, the gland of Luschka, &c. With the above two glands so called, the upper one of which at this early stage exists superficially behind the anterior vesicle, the growth of the brain convolutions is particularly connected. At an early stage the formative spinal cord is seen to consist of two portions or rather two pairs of columns, the posterior form the vermiform centre of the cerebellum, its lobes vegetating afterwards from the sides, and move forwards the corpora quadrigemina, whilst the anterior pair more directly take their course towards the pituitary. The four columns are connected together before they diverge. The insertion of the nerves at this early stage agrees with what is generally taught. It may be said that the posterior columns go to form the thalami, while another portion of these columns on each side is destined to the medullary portion of the hemisphere. The anterior columns, directed as above mentioned, rise up from before and below the thalami to form the internal and external folds of the hemispheres upon the anterior cerebral vesicle, the corpora quadrigemina being the middle and the cerebellum the posterior vesicles. The internal folds, in an embryo of eight or ten weeks, appear running lengthwise from the front of the brain; later on the upper fold turns down and unites with the lower one (which is the gyrus fornicatus) forming a cavity, which, however, is not the lateral ventricle, but becomes solidified. Like these gyri, the corpus callosum, formed by the coalition of two folds from each side, also gradually extends backwards. A little later we can make out, on this inner surface of the brain, the well-known features of the adult brain, the quadrate lobule rising obliquely backwards from the gyrus fornicatus, and further back the occipital lobe with its calcarine fissure. Mr Callender considers the left convolutions to be the earliest in development, though Dr Crichton Brown finds from his weighings that the right hemisphere in the adult is the larger. On the external surface of the brain, at about the same period of growth or soon after, the surface is marked by regular fan-like folds; the fissure of Rolando seems indicated, but the folds can hardly be identified with those of the adult brain. The embryonic brain now unfolds, thickens, and extends behind and downward; consequently the anterior and posterior horns of the ventricles are formed, the latter by the wrapping over of the crowded posterior folds. The bends in the brain and its pedicle also disappear, the cerebellum becomes covered, and the pineal gland is removed from the occipital surface accompanying the lowered quadrigemina to where the membranes enter the ventricles, at the transverse Sylvian fissure, which membranes are well described by Mr Callender. In the *Journal of Anatomy and Physiology* of 1874, this portion

of anatomy is elucidated in the editors' report of a paper by Key and Retzius. "By these investigations and by the former papers of the authors it is demonstrated that a continuous serous system pervades the entire nervous system from the ventricles of the brain, the subarachnoid spaces, and the sheaths of the vessels in the brain and spinal cord, to the extreme ramifications of the peripheral nervous system."

In consequence of the above-mentioned crowding and puckering of the folds at the hind extremity of the hemispheres this portion of the brain necessarily becomes twisted on itself, at first outwards, then downwards, and finally inwards, forming the spheno-temporal lobe, having within the hippocampal gyrus and hippocampus itself, which is a gyrus tucked inwards into the continuation of the Sylvian fissure, entering here what are called the inferior horns of the ventricles, the same crowding, accounting in a similar way for the lesser hippocampus in the posterior horn.

We think the formation of the brain may be illustrated so:—Take a fan and mark on the outer ribs, one-third upwards, two spots to indicate the pineal and pituitary; when expanded suppose the posterior extremity bent down outwardly towards the spot indicating the pituitary gland; the posterior edge will represent the hippocampal gyrus, and the folds situated nearest this edge the supra-tentorial surface. By such a curve, too, the extremities of the gyrus fornicatus and the longitudinal margin of the hemisphere, to which we may add the fornix, are approximated towards the grey matter near the pituitary gland, much as Foville teaches, the posterior curve of the corpus callosum not extending so far back.

The intrinsic structure of the nervous system is still imperfectly known notwithstanding many labours. The course of the fibres or medullary matter, and the disposition and differences of the grey matter, have been investigated with the aid of the microscope and of transverse (Querschnitte) and longitudinal sections (Durchschnitte) by Reichert, Luys, Gerlach, Meynert, &c. of whose writings we avail ourselves. The last anatomist, as well as Kölliker, Arndt, and also Beale, Cleland, Clarke, and others, more recently have endeavoured to make out the disposition of the cells and their processes and nuclei. It may perhaps be said that large pyriform or fusiform cells abound in motor parts; smaller or vesicular ones, sometimes aggregated into glomeruli, in the sensory parts.

Professor Turner, in *Journal of Anatomy and Physiology*, 1879, and Dr Dodds. *id.* 1878, give reports embracing an account of what has been done on this point with regard to the nature of the nervous cells, and the latter, in addition, shows the feasibility of supposing that direct and uninterrupted fibres exist between the spinal cord and the convolutions.

There is a paper in the first number of *Brain* by Mr Lewis, on the "Comparative Structure of the Cortex," showing that there is a distinction of motor sites in the brain convolutions, situated principally before the fissure of Rolando, marked by clusters or nests of great ganglionic cells; it is becoming evident that the forms, disposition, and many or few processes, &c., of the

cerebral cells have a relation to brain function. Meynert gives the different types for most parts of the brain; these are, with respect to the convolutions—(1) a common or five-laminated type of the cortex of the convolutions of the vault of the hemispheres; (2) the type of the occipital apex; (3) the type of the Sylvian fissure; (4) the type of the cornu ammonis; (5) the type of the bulbus olfactorius.

In divisions 2, 3 and 4 the general type may be varied, or its constituents re-arranged, constituting in 2 a poorer formation. In 3 and 4 the large pyramidal or fusiform cells abound in their proper layers; but in 5, the formation of the olfactory bulb or lobe, called the olfactory nerve in man, we have small nuclear-like cells abounding, the true olfactory nerves extending to a stratum glomerulosum on the surface of the bulb, which last has been considered analogous to the retina; and indeed the nervous attachments at the base of the olfactory lobe may be arranged analogously with the optic tract, the connection of the olfactory with the fibres of the anterior commissure forming an olfactory chiasma, for which, however, there appears no reason in regard to smell. A structure of corresponding cells is seen in the neighbouring extremity of the corpus striatum; but *in toto* this olfactory region presents in man but a rudiment of what it is in many animals.

The posterior cornua of grey matter in the spinal cord do not abound in the groups of large cells seen in the anterior cornua; it is probable that with these anterior large cells the motor-roots of the spinal nerves are connected through the *nerve* processes of Deiters, whilst the same cells give off *protoplasmic* processes, through which their union with the descending motor strands of the cord is effected. The arrangement appears different in the posterior cornua. The sensory nerve-roots, instead of combining with large cells, pass in part through the *substantia gelatinosa*, immediately dividing into a fine nerve plexus, which also extends further forward in the cornua—in part traverse the posterior columns before helping to form the above plexus. This plexus is here endowed principally with nerve-cells of smaller size than those of the anterior cornua. Vertical fibres ascend within the grey matter of the posterior cornua, and also through the posterior columns, the existence of which, and of the anterior and posterior commissures before and behind the central canal, certainly admits of a belief in both an ascending cerebral and cerebellar communication, and also of decussed or commissural paths administering to reflex or combined action. The grey substance and its ascending fibres might be assigned (in accordance with Brown-Séquard's experiments) to cerebral afference, the posterior columns to cerebellar. The former would also appear to convey the sensations of temperature and of pain, whilst the latter (perhaps solely) pertain to muscular sense.

In reflex spinal action the muscles contract in a somewhat orderly manner even in the new-born infant, where no experience or practice can be supposed; hence it might appear that within the cord itself some arrangement exists co-ordinating the flexors in contradistinction to the extensors, or rather flexion in opposition to extension; and the further question arises—whether, as the extensors answer most to dorsal

nerves, there is an arrangement for the bipartition of the anterior spinal strands? and whether minor portions of the motor fibres for the dorsal part of the body go backwards in the cord itself and join the posterior roots? as some anatomists believe, which roots therefore must be both sensory and motile, as far as the posterior part of the organism is concerned. It however is not a view we take, and fortunately does not trench upon our explication of the mode of connection between the supposed motile action of the brain and its peduncle above the pons. Deiters, Clarke, Luys, and others, maintain that fasciæ decuss and cross over in the region of the pyramids *towards* the posterior roots of the opposite spinal nerve. At this point it may be inquired—Are the inter-spinal ganglia in any degree distributors of motor nerves? or are they solely commissures of the anterior and dorsal, and other connecting sensitive nerve branches? which last we should suppose to be the fact, a synæsthesia being so effected; a reversed distributive action being facilitated in the motor nerves, as far as mechanical arrangement goes, by a plexus, the axillary for instance.

Theory might induce us to assimilate the slender columns on the dorsum of the spinal cord, which appear to terminate with the cord itself, and of which there is an intimate commissure within the dorsal fissure, with the two slender columns, which may be distinguished below the pyramids and down the cord in front, intimately united like the preceding within the anterior fissure. If the dorsal appertain to the extension of the trunk the ventral columns would to its flexion—the muscles concerned in both escape being affected in paralysis.

The arrangement for the nervous supply, dorsal and ventral, takes place at the roots of the nerves rather than in the medulla. The number of spinal nerves constituting the plexus supplying a limb has a relation to the number of the distal divisions of the limb throughout the animal series; also, it may be added, that the nervous roots forming the extensors, are upon the whole, the more anterior as regards the body.

Dr Broadbent does not admit separate conductors to the brain for pain, temperature, &c., and makes a proposition expressing that "the spinal cord is capable of co-ordinating—*i.e.*, of combining—for orderly, purposive, or adapted action, all movements guided by cutaneous impressions," and its three chief functions are the balancing of the body when standing or walking, the bi-lateral association of nerves, and the crossed association of the anterior with the posterior extremities; but in man the spinal function must be often superseded by cerebral or cerebellar influence. With respect to spinal conduction a paper by Dr Rutherford in the *Journal of Anatomy and Physiology* for 1873 may be consulted.

Clarke describes a column of cells found especially in the dorsal region of the grey matter, and rather behind the central canal, peculiar from the absence of any evident nervous processes, but in which Gerlach traces strands outwards and backwards towards the posterior spinal roots, which we might perhaps connect with the lateral or respiratory system.

Dr Ross, in the *Medical Times and Gazette*, October 27, 1877, examines the structure, in the infant of a month old, of the spinal

cord; it then consists of the central grey matter, and two anterior and two posterior bundles at the sides at the roots of the nerves; other bundles are added on each side, two pyramidal ones both together forming one of the pyramids; a variable number of fibres from each pyramid pass directly down the cord close to the anterior fissure; the larger portion decussate with those of the opposite side proceeding backwards and forwards. A fifth bundle occupies a lateral surface of the cord and connects the cells of Clarke's column with the cerebellum. The sixth system is a wedged-shaped bundle lying between the posterior nerve roots and the posterior fissure, ending above in the slender columns. Dr Preston studies the cord in the same way; and, after Flechsig, makes out seven tracts on each side; these are, in the order of their formation—(1) fundamental tract of anterior column; (2) fasciculus cuneatus (Burdach); (3) anterior mixed tract of lateral column; (4) lateral bordering layer of grey substance; (5) Goll's column; (6) direct cerebellar tract; (7) pyramidal tracts. The first four are commissural between different portions of the cord; the three last, increasing in size from below upwards, serve to connect the cord with the brain—the pyramidal tracts with the cerebrum and basal ganglia, the cerebellar tracts with the cerebellum, and Goll's column with the medulla oblongata (J. Crichton-Browne in *Brain*).

Upon the whole it would appear that the spinal cord is not, *per se*, an independent organ, as Volkmann surmised, its fibrous strands increasing as they ascend, and the grey matter alone where the great nerves are given off. On the contrary, it is as it were the highway of nervous conveyance between the brain and the nerves of the periphery. Still it has some independent power, automatic, and of nervous reflexion; but whether these two powers are attributable to distinct cells, those without and those with nervous processes, is only matter of theory.

The sub-pyramidal decussation, in contradistinction to an inter-pyramidal one of finer fibres, appears to account for the crossed action of the cord as far as motor influence is concerned; it is a question, however, how far down the cord a true decussation takes place. If the decussation is total at the pyramids without any lower down, as taught by Meynert and Hirschfeld, then division of one lateral half of the spinal column in the living animal in any part much below the medulla oblongata, ought to produce total paralysis on the same side, but not on the other, though Brown-Séquard says there is some of the latter, as there might be, if Foville and Valentin are correct in supposing, a true decussation all down the spinal cord. Apparently the lower and inner parts of the pyramids decussate and go backwards, while the outer portions join the descending olivary tracts, and form the anterior columns; the posterior slender columns would also appear to descend a good way, though this is rather in opposition to certain views of their formation: the main posterior columns, where the extremities of the nerves are received, and the restiform bands, appear to us continuous.

Brown-Séquard's experiment of dividing the internal grey substance of the cord seems to show that ordinary sensation is conveyed upwards

through the inner substance of the cord in its opposite side. Subjects with great congenital atrophy of one side of the body have the opposite side of the brain atrophied, but with regard to the lobes of the cerebellum, that one on the side of the atrophy in the body is wasted; it follows from this, that if the posterior columns are the conveyors upwards of any kind of impression, as the muscular sense, there can be no *spinal* decussation of these columns.

In cases where a limb has been long amputated, the posterior roots of the spinal nerves, the grey matter of the cord, and especially its posterior columns, as far as the medulla oblongata, are atrophied (Dr Dickinson, *Journ. Anat. and Phys.* 1868). Dr Dreschfeld also has shown that this atrophy affects the cells of the posterior horns, from desuetude we presume (*id.* 1880).

Supposing that the status of the muscles is rendered to the cerebellum by the posterior columns and restiform tracts, or rather, perhaps, their internal portions, the cerebellum appears sufficiently rich in organisation to receive complicated impressions, to separate, analyse, and distribute, as well as to combine and co-ordinate, this being accomplished by it through its anterior peduncles and the pons, by its disturbing momentum; the cerebrum willing an action, but the cerebellum subservient, ruling elaborate movements which, in this, become more involuntary in nature. We do not, however, mean to exclude purely cerebral voluntary motor power, or the reverse, inhibitory influence; hence the necessity for an afferent sensory as well as an efferent motor tract through the crus, between the spinal cord and the cerebrum, the former independent of the loop of the cerebellum; the internal grey matter might be the medium, or rather the fasciculi, running upwards beneath the fourth ventricle (the posterior longitudinal spinal fasciculi of the tegmentum), though, we should add, that, according to some physiologists, the motor nerves themselves can telegraph upwards the state of the muscles which they supply, or that it can be estimated centrally, from the motor power required. We cannot think, as we understand Luys to say, that the cerebellum receives no afferent strands, and that it is an automaton having three processes or exits of power, or what he terms a trilogie of independent motor impulse, giving it higher powers than the cerebrum itself; we cannot see how it can act at all without receptive influence; it could not govern even the involuntary movements, whereas it seems to influence even the voluntary initiated by the cerebrum; probably it is placed in connection with the cerebrum by some constituent of the tegmentum or upper peduncle. Its vast foliated expansion must have relation to some great function, and it appears likely to that of the numerous muscles concerned in locomotion, &c. There is no crossed action in the cerebellum itself, but only through the medium of the pons, because it is certain that the right or left cerebellar lobe corresponds to the left or right cerebral crus.[1]

[1] The theory advocated of the function of the cerebellum seems fairly supported by the anatomy, but it is also corroborated by the experiments of division of its brachia, which have been long known, and the effects of which on locomotion have not been nullified.

According to Meynert, there is a connection between the cerebellum and corpus striatum—the latter part has cells of two distinct kinds, of which one kind forms a loop with the cerebellum through the crusta, substantia nigra, and pons, the crusta diminishing much in size at this part. This, probably, is afferent as regards the cerebellum, being a processus cerebri ad cerebellum.

Of the action of the cerebellum other theories, besides the one favoured here, have been advanced—as Ferrier's: that it governs the movements, but only as influenced by vision. The special character of its cortical nervous corpuscles may be found to have a bearing on the question; certain of the outer cells appear to be recipient, while other larger cells, those of Purkinje, arranged in regular series through the inner cortical layer, appear to have both exterior processes, which Meynert connects with the brachia to the pons, and centrally direct solitary processes connected with the lower peduncles. These cells may well be considered as constituting a commissure between its brachial and peduncular systems.

Dr Tuke, in contravention to there being any psychical or physical indication during life, in consonance with theories which are held by most physiologists respecting the cerebellum and co-ordination through the same, instances several cases of atrophy or destruction of the cerebellar hemispheres without such indications (*Journ. of Anat. and Phys.* 1873).[1]

We are disposed to accept Ferrier's theory in part, and that vision subserves the cerebellum from above as the muscular sense does from below—vision through the tegmentum, in which case the particular element of the tegmentum concerned must be afferent to the cerebellum and not to the cerebrum; this particular element is probably the valve of Vieussens.

Broadbent says—"The cerebellum co-ordinates movements guided by vision (or other senses, as smell in the mole for instance), or combines the general movements of the body rendered necessary by special actions ordered by volition." Drs Howden and Brockman give instances analogous to the one of Van der Kolk; in the latter case, the right cerebral hemisphere, the crus cerebri, the corpus albicans, and optic nerve, were atrophied; whilst the left cerebellar hemisphere was correspondingly wasted (*Journ. of Anat. and Phys.* 1875–76).

[1] In the following case, a want of power of co-ordination attended disease of the cerebellum. The patient, a girl of fifteen, had from her childhood been subject to deafness and headache. Since a kind of fit, seven weeks back, she has had a slight hesitation in speaking, and the right arm and leg are both deficient in sensation and motion, the right leg being very slightly dragged. "When she walks it is with the head steadily fixed, and the eyes looking straight at the ground before her. If desired to lift her eyes from the ground her gait becomes unsteady, and she appears unable to regulate her course." The *post-mortem* showed that the brain substance was generally soft, and the ventricles filled with serous fluid. On coming to the cerebellum, a cyst was found in the right hemisphere containing laudable pus in large quantity. The auditory nerve was especially soft. See also a case reported by Dr Ferrier in *British Medical Journal*, December 11, 1880.

The disposition of the formative and efferent bands of the cerebellum is pretty well understood in their broad features, but much relating to it has not been worked out; its lower peduncle is composed of two parts, and the inner part enters into relation with the roof nuclei, discovered by Stilling, situated below the central lobule of the superior vermiform process; the two inner parts also decussate and then become related to the posterior medullary velum, the flocculus, and auditory nerve. We presume that this lower posterior peduncle in part may mediately or immediately ascend to the cerebrum. The superior peduncle of the cerebellum has its insertion or origin within the dentate nucleus of the cerebellum, differing in this from the other two peduncles. It is rather bold, what some might be inclined to do, to assign the flocculi, which, in some of the lower animals are surrounded by the semicircular canals, to the nerve of hearing. Perhaps, in regard to the lateral lobes and central vermiform body of the cerebellum, the first may have most relation with the limbs, the last with the trunk of the body.

Of the so-called respiratory tract in the medulla oblongata and top of the spinal cord, little of a precise nature can be said; we do not see that respiration requires other than nerves of a motor and sensory function, or of a mixed nature, as we may suppose the acknowledged respiratory nerves to be from their intermediate origin, yet do they appear remarkable in being interwoven with other nerves at their roots, and for the special latticed or retiform structure of the part of the bulb where they arise, interlaced as it is with numerous fibres arcuatæ, and effacing the ordinary disposition of the medulla.

Little definite being evident respecting the respiratory focus in the medulla oblongata from the anatomy, perhaps we may infer more from physiology and pathology. Both respiratory feeling (*besoin de respirer*) and respiratory movements, though seated primarily in the region of the medulla oblongata, are not entirely withdrawn from cerebral influence; hence, when the brain is oppressed the breathing becomes impeded. Swan especially, shows how this connection is effected anatomically. Sentiment likewise, as well as speech, is connected with respiration. On the other hand, in infants, certain spasmodic respiratory states, laryngismus or pertussis, so far as the latter is simply a spasmodic disease, become more urgent by inordinate cerebral or cerebellar action, or from an ill-matured state of the instinctive respiratory process. The great importance of the respiratory function is somewhat contrasted with the smallness of its medullary centre; and the nerves here given off seem rather superadded than of the ordinary spinal type, they all make their exit from the interior of the skull above the point of origin of some of their roots. Respiratory muscles may in addition be otherwise supplied, as those of the face, tongue, throat, and chest. The fifth nerve, the portio dura, the vagus, the glosso-pharyngeal, the hypoglossal, and the spinal accessary are all more or less connected with the respiratory reticulated region, and must be united in many sympathetic actions.

With such a function as we attribute to the cerebellum, the sense of hearing may be well allied. It is subservient to all the movements

of animals, and in man especially, to movements of a higher kind, indeed, in him it is intimately connected with his higher sentiments, and hence must be transferred upwards through the central grey substance probably, or in some other unknown manner. Meynert teaches that the auditory nuclei have no structural connection otherwise than with the cerebellum; at the same time he admits the feasibility of considering the upper cerebellar peduncles to include auditory tracts analogous to the optic; some, however, would sooner fix upon the valve of Vieussens thereto.

Higher up the great divisions of the peduncle of the brain become defined as an anterior motor (crusta) and a posterior sensory (tegmentum) portion. We presume that the posterior spinal columns are continued upwards into the restiform bodies, which they help to form, as these latter do the cerebellum, being the bearers to it of the status of the muscular actions, in contradistinction to common tactile sensation, conveyed upwards by the internal grey substance or the fasciculi above mentioned. The cuneate and slender columns at the back of the oblongata may take part in this, connected as they are below with the posterior columns, and indeed formed, as they are considered to be, by the crossing over of the arcuate fibres of the restiform, threading the bulb, and connected moreover with the olives, each restiform forming or helping to form the cuneate and slender columns on the opposite side (?); it is not possible, however, to trace these last upwards through the fourth ventricle.

The posterior longitudinal fasciculi seen on the floor of the fourth ventricle are continuous below with the posterior sensory spina elements, and above go under the corpora quadrigemina to the third ventricle, the loop and Sylvian fissure: in the middle line of the ventricle below, however, the anterior motor columns ascend and project as the round fasciculi or eminentiæ teretes. The olivary bodies give another element to the crus above—the fillet; these olivary bodies have already been mentioned as united below with the outer undecussated fasciculi of the pyramids to form the median portion of the anterior spinal columns, as well figured in Hirschfeld's plate.

This fillet, connected above with the quadrigemina, also giving fasciæ more forwards (possibly a commissural respiratory cord) is seen, when we tear down through the locus niger, the tegmentum from the crusta, to merge into the olivary bodies as just said.

The above fillet, in part together with the respiratory tract, Swan carried upwards through the ring of his involuntary or middle tract to the summit of the cerebrum; but in itself it may be considered as a processus inter corp. quad et medullam.

Above the pons, of which each side half consists of the strands from the cerebral hemisphere of the same side, but interlaced by loops from the cerebellar peduncle of the opposite side, we may say the crus of the brain commences, but here fortified by pigmented cells (locus niger) which cease below. The anterior part of this crus or brain peduncle (crusta) seems simple enough in its arrangement, the outside bands, however, trending to an early crossing inwards. Swan's idea of the arrangement of the bands has been mentioned. Meynert teaches,

moreover, that the external and posterior part of the crusta receives strands from that portion of the cerebrum which we have considered to belong to its sensorial function, the temporal and parieto-occipital lobes, &c., and that these external fibres, more or less connected perhaps with the optic tract, cross over the other bands, and so, but through the upper or finer pyramidal decussation, trend towards the back part of the spinal cord. He considers them exceptional to the general motor function of the crusta, in opposition to that of the tegmentum which must be in the main sensory. There are other interlaced and inflected fasciæ in the crusta as those from the external corpus striatum in relation below with the third nerves and nates; fasciæ from the internal corpus striatum, &c.

Whilst the structure of the crusta or motor part of the brain-peduncle is tolerably evident, the intimate composition of the tegmentum or sensory portion is a more difficult study. Broadly speaking the latter has strands which are principally afferent of sensation to the cerebrum, though certain of them may transmit sense-impressions downwards. The principal connections above are the thalami and the cerebral convolutions, or the latter through the corpora quadrigemina and their brachia; below, the connections are the cerebellum, the medulla oblongata, and spinal cord. The internal grey matter around the central canal is no doubt one of the tracts by which sensation is conveyed upwards, trending to the intraventricular grey matter, and connected in front with the tuber cinereum, corpora albicantia, pituitary, and pineal bodies.

Foville places in apposition with these last the anterior terminations of the sensory and middle tracts, reflected outwards in the quadrilateral grey space to the points of the temporal lobes: we would not, however, separate these from the crescentic arches of Swan, or the substantia innominata.

Through the posterior tegmental portion of the crus, and in the direction of, but beneath, the corpora quadrigemina, ascend the posterior sensory tracts of the cord, so far as they have not been exhausted, or if they have been so exhausted, which hardly seems the case, they are yet virtually continued upwards through the grey substance, longitudinal fasciculi, and the cuneate and slender columns, which the restiform columns or inferior peduncles of the cerebellum have, according to Meynert, helped to form; and there are other bands which are constituents of the tegmentum. These are *in toto* the upper peduncles of the cerebellum, the valve of Vieussens, the posterior longitudinal fasciculi, the inner grey ganglionic matter, the fillet, the corpora quadrigemina, and also fibres interlacing with the anterior crusta. The posterior stratum of the pons would appear to belong to the tegmentum, and might be referred, as Meynert suggests, to the sensory and olfactory region about the caput of the corpus striatum above. Our view, however, of the functions of these constituents is in brief the following: the upper peduncles, crossing above, are afferent upwards, connecting the cerebellar lobes with the opposite cerebral; the longitudinal fasciæ convey upwards from the medulla to the cerebrum together with the central grey substance; the fillet and quadri-

gemina are respiratory, and the latter, moreover, especially connected with the cerebral nerves of sense and motion; probably the valve of Vieussens conveys from the cerebellum to the quadrigemina, or perhaps *vice versa* for the most part.

Kölliker makes the elements of the medulla oblongata to be as follows, and thus connected with the medulla spinalis :—

The anterior columns of the cord form or join the—
  Pyramids (outer part).
  Olivary columns (contributing to the peduncles of the cerebellum and constituting also the)
  Fillet (and tegmental fasciæ).
The lateral columns constitute the—
  Lateral fasiculi (contributing to the restiform bodies and tegmentum).
  The decussation of the pyramids.
  The eminentiæ teretes.
The posterior columns constitute the—
  Fasciculi graciles (going to the tegmentum).
  Fasciculi cuneati (to the peduncle of the cerebellum) and tegmentum.

The region of the corpora quadrigemina is formed of different elements and cells; their ganglionic parts, situated above the iter or communication between the third and fourth ventricle, and covered by medullary fibres direct from the cortex of the posterior part of the cerebrum, are enclosed below by another tegmental lamina; their capsules thus formed decussating in the middle line, give origin to the *processus corp. quad. ad cerebellum*, or valve of Vieussens; anterior to the iter or aqueduct lies that portion of the tegmentum seen below at the region of the lamina perforata posterior, and below this on each side is the crusta.

The true decussation of the tegmentum is other than the above decussation of the capsules, it is of the upper peduncles of the cerebellum below the corpora quadrigemina. Within and above is the aqueduct with the posterior longitudinal fasciculi at the sides and floor, also descending roots of the fifth nerve, rich in vesicular ganglionic cells; originating from the mid-fasciculi are roots of the oculo-motor nerves marked by large ganglionic cells, decussating and derived above, however, from the lenticular nucleus *via* the loop or collar or deep stratum of the so-called ansa and crusta. The superior peduncles of the cerebellum or *processus cerebelli ad cerebrum* after their decussation are in opposition to the lemniscus or superior lamina of the fillet.

The superior peduncles form the so-called red nuclei, the two fellow parts decussating behind the nates, as said before, between the posterior longitudinal fasciculi and the layer of the fillet, the tegmental fascicles from the spinal cord being pressed outwards. They are more prominent below than above, forming the lateral wall of the fourth ventricle, inclosing the valve of Vieussens from the corpora quadrigemina, and unite also the vermiform lobe of the cerebellum with the fillet. The above red nuclei on the one side are connected with the

thalami and corona radiata; on the other, as just said, with the superior peduncles, *i.e.*, the processus cerebelli ad cerebrum.

The antero-lateral part of the tegmentum interweaves with the descending root nuclei of the fifth nerve, forming a kind of upper interlaced or latticed region (analogous to that of the medulla oblongata).

The entry and exit of the elements of the crus into the cerebrum is not absolutely a simple matter; the substantia innominata or ansa peduncularis of Gratiolet (being probably the crescentic arches of Swan) is a disposition of the constituents of the crura, near where they are crossed by the optic tract; one of its components, the loop, belongs to the crusta, and is formed by the fasciculi of the lenticular nucleus of the corpus striatum; the next is a ganglionic expansion, formed by the posterior longitudinal fasciculus from the tegmentum, and expanding above into the external capsule of the lenticular nucleus and Sylvian floor; another is the inferior peduncle of the thalamus connected with the cortex of the Sylvian fissure and the temporal lobe; the fourth constitutes the temporal portion of its zonal or encircling stratum. The connection of the tegmentum by the posterior longitudinal fasciculi and their laminæ of the ansa with the island and capsule of the lenticular ganglia of the corpus striatum is not, like that of the crusta by its loop or collar, effected through the means of the laminæ medullares of the latter; which last, centrifugally it may be supposed, conveys motor impressions to the lower oculomotor nerves.

The tegmentum, as far as the thalamus is concerned, is connected with it, with decussation or not, at various points—the posterior commissure, its medullary laminæ, the peduncular ganglion of the pineal, and by the distinct ganglia situated below the thalami called the red nuclei, which are connected behind with the anterior peduncles of the cerebellum.

With the tegmental system the optic tract is in union through the corpora quadrigemina, and also through the virtual prolongation of the tegmentum through the grey substance of the ventricles. Here it comes in relation with the basal optic ganglion near the chiasma, and also with the anterior distribution of the fornix. The union of the optic tract with the tegmentum is specially effected by the corpus geniculatum externum, in a peculiar structure[1] consisting of alternate

[1] A not uncommon form of transient hemiopsia seems due to the structure of this body; it is described by Dr Airey, and an abstract of his paper is given in *Scientific Opinion* for 1870, but the present writer may describe the affection as for some years it has occurred to himself, after close study, unusual exertion, &c, It is often attended with headache, and the attack, from beginning to end, may last half-an-hour. It commences with the appearance of a small cloud a little above and to the right of the field of vision. At this spot a few scattered lines and angles appear, and gradually a line of bastions or zigzag, such as we see in Norman architecture, takes a circular or oval form, but incomplete below. It is luminous and presents a peculiar waving motion; after enlarging, it disappears by becoming shorter; occasionally the circle is intersected by a second further inwards. It is equally present whether the eyes are open or closed, more luminous in the latter case; any partial pressure on the globe of the eye produces no change; but the spectrum is affected by pressure on the carotid.

layers of white and grey substance; the tract is then in connection with the inner corpus geniculatum, with the nates and testes, the cerebellum, and in the lowest vertebrata with the cord.

The sensorium appears to be informed of the movements, as modified by cerebellar action, through the upper peduncles or processus cerebelli ad cerebrum. In this region, too, together with the tracts above enumerated, is the connection of the optic tracts with their motive adjuncts or ganglia, and hence is conveyed upwards the intimation which muscular action of the optic motor nerves adds to the mere sensation of the retina.[1] These motores oculorum nerves have no connection with the cerebellum, at least the principal ones, the third pair, and consequently the action of its fellows, is less separable than those of a nerve given off below the cerebellum as the sixth, and therefore must be antagonized by a nerve pair, of which either right or left can be separately excited. In the mole the optic nerve seems only a light —not an object organ, and in the parasitic and sessile cyclopterus it has no other connection with the cerebrum than a slight one with the grey matter before the pituitary body—its further insertion in other animals in the geniculata and quadrigemina and connection with muscular nerves gives further powers of sight; and further still, its connection in the higher animals with the thalami and through them with the cortex of the brain.

The recognised origins of the so-called cranial mixed or motor nerves are such as to admit earlier or later of an union, either commissural or decussated, but generally speaking no further tract upwards to the cerebrum can be assigned to them, though it can with respect to the third and fourth nerve *via* the lenticular nucleus.

Smell in man may be principally connected with the grey substance at the base of the brain, and with the amygdala (Luys); in most Mammalia the more highly developed nerves run further back through the spheno-temporal lobe and hippocampus, as well as through the gyrus fornicatus, so that such brains have been termed olfactory. The olfactory lobe or tract, at first evidently in union with the internal and external olfactory convolutions, is connected by a medullary tract to the perforated and internal grey substance and so to the fornix; its internal or medial connection is also the anterior extremity of the gyrus forni-

[1] That the fourth nerve is liable to paralysis would appear from the following:— A collier has complained of double vision and headache for six months. They came on gradually, he at first noticing a waving of the candle in the pit. The eyes ached much when used. The peculiarity is seen chiefly when he looks upwards or at a face before him. This peculiarity is a rotation of the eye on its antero-posterior axis when looking at an object. The pupils contract as usual. The rotation is inwards and downwards, that is, from the temple over the cheek towards the nose, the action would seem to be produced from the inferior oblique muscle having lost the effect of its antagonist, the superior. The crossing of these nerves is in the valve of Vieussens external to the point of origin.

Ptosis is often a prelude of brain affection, as is also defect of nervous power in the hypoglossal nerve. In the latter case the major affection may be in abeyance for years, the former in one case continued six months, eye everted, pupil somewhat dilated, articulation also somewhat affected; apoplexy and paralysis then came on; the tongue was put out, directed to the right, which was the side paralysed.

catus, together with some minor bandelettes belonging to the corpus callosum, septum lucidum, &c.

Hearing is more especially united with the cerebellar centre of locomotion, which, when uncontrolled by the cerebrum, it is so concerned in directing, and secondly with the conscious cerebral centre by means of the grey matter of the cerebral cavity, or the valve of Vieussens it may be.

Taste apparently is only perceived through the glosso-pharyngeal, and the rationale of its centre seems much as is the case with the nerve of hearing. Thus the sense nerves are inserted in various ways immediately or mediately into the cerebrum or its ganglia. Yet if taste is inherent in the glosso-pharyngeal, as might be inferred from the parts supplied by that nerve being precisely the seat of taste, it seems strange that taste and smell, so closely allied in their nature, should be so far separated in their cerebral centres. We might from this last consideration be disposed to assign taste to the gustatory nerve, were it not from experiment showing that the true gustatory surface (of the tongue and palate) is supplied by the glosso-pharyngeal directly or indirectly, and besides, the latter nerve has most relation with the pharynx, as its name implies, so intimately concerned in the act of swallowing.

With the olivary tracts or fillet, according to Solly, the fourth nerve, the motor root of the fifth, the sixth, the portio-dura, and the ninth nerves, are attached; but the so-called origin of the cerebral nerves would be a matter for a volume rather than an essay like this. All the cerebral nerves except the first four are in relation at their origin or insertion with certain nuclei of sensory or motor cells situated principally in the fourth ventricle, and amenable to the demonstration of transverse sections, chemical and colouring re-agents, and the use of the microscope. Hence the importance of the ventricular floor. These nuclei have been so studied at this point by Stilling, Clarke, Dean, Meynert, &c. The account given by Meynert is ample enough as far as the subject is understood, and we must refer to him. Physiology and anatomy do not appear to differ in this point; the fifth nerve has, as has long been known, several places for its deep insertion. The abducens oculi we have already said to be influenced by the cerebellar action according to our theory, but it is also considered to be connected above with the corpora quadrigemina, and it is synenergetic with the third nerve. The facial, considered by Winslow from its large distribution to be a smaller sympathetic, has numerous points of orgin; the auditory nerve cannot fairly be traced to the cerebrum, but appertains rather to the cerebellum, so necessary as hearing is a guide to movements.[1] The three respiratory nerves Meynert arranges as a lateral system of mixed function, in relation to the reticular structure of the medulla oblongata, a structure which appears to account in some degree for the numerous liaisons which there must be of nerve roots at

[1] The auditory nerve includes a softer and less fibrous portion, and this it derives from the cochlea, which is most developed in the highest vertebrata, birds, and Mammalia and it is this portion which theory would lead us to attach to the cerebrum.

this locality. As to the separate and special functions of the three nerves constituting the eighth, it may perhaps be said that experimental physiology has not thrown unmixed light upon them; the spinal accessory is no doubt, as its name expresses, a motor adjuvant to the pneumo-gastric, whilst the glosso-pharyngeal, with its jugular ganglion, seems as clearly sensitive distributed to the internal ear, palate, tongue, and upper pharynx. The pneumo-gastric, called the middle sympathetic by Winslow, receiving through its ganglion branches from the adjacent petrous ganglion of the last, and conjoined with the accessory in the ganglion or plexus of the trunk, must be considered a mixed nerve, but principally motor, but sometimes inhibitory of motion. Its supply to the larynx is, as is well known, very noteworthy. The hypo-glossal has evidently a motor, and like the other motor nerves is crossed at its roots. As the nerve of speech it should be, as it is, connected with the trunk of the ganglion of the great nerve of respiration; it also, as is well known, supplies the muscles connected with the tongue, and is reinforced from the cervical nerves through the descendens noni, &c.

Supplementary to the above, it should be said that Stilling's nerve nuclei are principally situated on the lozenge or rhomboid-shaped floor of the fourth ventricle as follows:—Considering the space itself as marked above by the convergence of the superior peduncles, and below by the divergence of the fasciculi graciles, divided also by the median furrow, and crossed in the middle by the striæ medullares of the auditory nerves. At the upper angle are the eminentiæ teretes, and without these appear the fossæ cæruleæ caused by cell clusters belonging to the sensory roots of the fifth nerve. Lower down is the auditory nucleus, and below this that of the glossopharyngeus. In the middle line are the nuclei of the facial and sixth pair. In the lower portion of the space is the grey nucleus on each side common to the vagus and accessory nerves, and in the middle line the emiteretes and the nuclei of the hypoglossal.

The small motor root of the fifth nerve in connection with one set of its sensory roots is derived perhaps from the vicinity of the aqueduct, and other sensitive roots from the nates, and others again ascend from the corpora gelatinosum of the medulla; the nerve also seems influenced by the cerebellum. Meynert makes the sixth nerve to be connected with the pyramidal decussation, and so of the facial nerve, the latter trending to different points of origin—descending, plane, and ascending. The nuclei of the auditory nerve are by no means simple though, as already said, no higher connection than the cerebellum is shown. The hypoglossal corresponds much with the sixth nerve in a motor origin and in its decussation. According to Schröder v. d. Kolk this nerve's origin is connected with the olivary body.

Dr Ferrier's experiments give a cerebral centre to the three nerves of smell, taste, and hearing in the hippocampal lobe. In this case, might not the fornix be the conductor of the posteriorly received sensations of taste and hearing from the central grey matter?

The fifth nerve appears to be the double-rooted spinal nerve of the head, if it be not the union of three, if not four, nerves analogous to spinal

ones, motor roots being only furnished to the last division; the rest of the face and head being supplied by the seventh and cervical motor nerves in addition to the fifth. A rationale, which may assign each division of the fifth to an especial cranial vertebra, seems difficult to discover. Valentin treats upon this point in the *Nevrologie.* This seventh, or facial nerve, does not answer to a regular spinal nerve, or to either portion of one; it is *par excellence* a nerve of expression and of respiratory movement of the face, especially attached likewise to the internal ear and petrosal bone, the last being intercalated, and not of the regular vertebrate series. It is remarkable whilst in its bony canal for its connections with Meckel's and the otic ganglia, probably conveying motor power to nerves of the palate and internal ear, also for its communication through the chorda tympani with the sub-maxillary ganglia. This last nervous chord, with the three ganglion, may be considered as belonging to the sympathetic system, as also may the ophthalmic ganglion, a distributive or reflex function being also attached to them; and all the cerebral nerves, except those of pure sense, intimately connected with this sympathetic system. What the seventh is to the face, motor, yet of respiration and expression, the fourth nerve is to the eyeball.

The individuality, as far as sensation and perception are concerned, must be largely maintained by the continuity or solidarity of the grey ganglionic substance lining the whole cavity of the central nervous organs; not ignoring, however, the connection of one portion of the apparatus of organic life with another as maintained by the ganglionic sympathetic nerve, the heart with the lungs, or the stomach with the bowels or heart. Certain terminal and denuded grey surfaces in the brain and spinal medulla as the pituitary body, pineal gland, and filum terminale have been suspected to be, in relation especially to the central grey matter, the former to sympathise in disordered action of the organic nerves. It might also be opined that the appendages in question may be sensitive to impressions upon the nervous organs themselves, as a whole, as from succussion, shock, &c. This central grey nerve matter may be the seat of pain, or at anyrate of that general bodily feeling of *malaise* or exhilaration which may be our misery or comfort, to say nothing of more dangerous hyper-æsthesia.[1]

Dr Ferrier is disposed to connect the corpora quadrigemina with equilibration, locomotion, and emotional respiratory expression. The corpora quadrigemina have a variation as to size in relation to vision;

[1] In tetanus, according to J. Lockhart Clarke, the seat of lesion is the grey substance in the cord (see his paper in vol. xlviii. of the *Med. Chir. Trans.*) associated with a morbid condition of some of the peripheral nerves; two of Clarke's cases occurred under the notice of the writer of this. In another case of injury of the left thumb and index finger, the nerve going to the back of the thumb was much enlarged, the same nerve in the forearm injected, as was also the brain and spinal cord. In hydrophobia we might suppose the morbid action is directed to different strands in the cord, &c., sensory rather than motor, of which nature (sensory) the symptoms seem in the main to be. It appears remarkable that tetanus never occurs from the operations of dentistry, probably from the character of the nerves injured. In paralysis there is also dilatation of the central cavity of the cord and wasting of the strand concomitant with that of the muscles.

it may be inquired whether this relation holds with respect to both upper and lower pairs, or only to the lower, with which the optic tracts seem more especially connected, or whether they have any relation to the musculature of the eyes. Comparative anatomy ought to throw some light on this subject; it is not certain that any sense is in special relation to the upper pair, though they may have anatomical connection with those roots, which, in part, run backwards through the internal capsule, and form the anterior peduncle of the thalamus; the corpora quadrigemina exist well developed in many Cetacea, in which an olfactory organ scarcely exists at least under an unmodified form. The mole has the lower bodies small, whilst the hippocampi are large, and so in the monotremata. They are comparatively moderate in man, the upper ones largest in Rodents and Herbivora the lower in Carnivora. Through the adjacent bands the sensory afferent bands of the cerebrum must ascend to the thalami and cortical substance, communicating likewise with the lenticular part of the corpus striatum.

The connection of the thalami with the medulla of the cerebrum is well seen by placing the brain on its upper surface, and exposing the roof of the ventricle in its full extent, removing the hippocampal convolution of the spheno-temporal lobe. They are, on the other hand, certainly continuous with the corpora quadrigemina and the sensory strands, thus constituting a great centre, initiating movements by reflexion even directly without the exercise of volition (sensori-motor) being in immediate connection with the motor corpora striata; hence it is hard to refrain from movements if the feelings predominate though the will may disapprove.

It is the thalami which principally supply or receive the medullary strands of the middle temporal and occipital regions of the brain, a few excepted, which have a more immediate course behind to the crus; they (the thalami) are connected with the frontal lobes by their anterior peduncles. They also derive an inferior peduncle from the Sylvian fissure and temporal lobe, the third stratum of the collar or ansa; in this way also the external lamina or zonula layer is formed. The afferent strands of formation are the corpora quadrigemina and tegmentum, the latter ascending from the periphery. The fornix contributes also to the thalamus by its ascending and descending crura, connected also with the ventricular grey matter, stria cornea, and corpora mamillaria, &c. Of course the connecting fibres forming the above-mentioned anterior peduncle must run in a different direction through the internal capsule from those derived from the central medullary fibres of the cerebrum. The upper peduncle of the thalamus is derived from the ascending pillar of the fornix and gyrus fornicatus; the thalamus also is connected by its corresponding surface with the parietal, temporal, and occipital lobes.

The corpora striata, ventricular, and extra-ventricular are as clearly connected with the efferent locomotive strands of the crus as the thalami are with their afferent sensory strands.

In many cases the ventricular corpus striatum is continued posteriorly by its attenuated extremity along the inferior horn, præflexed on itself.

With respect to the inter-communication of the corpora striata and thalami, Luys connects the tegmentum, belonging to the sensory system, with the concentric septa of the external striata by means of fibres running beneath the thalami *via* his superior olivary bodies or red nuclei. He also connects the front of the thalamus with the corpus striatum by means of certain fibres bent upon themselves, which he calls cortico-striate, deriving them at their origin from the cerebral convolutions. Meynert connects the thalamus with the corpus striatum by means of the anterior peduncle of the former. But it would appear that there is a closer union of the thalamus and the corpus striatum accounting for sensori-motor action. There is the interlacement that takes place through the convolutions and deep substance of the island; besides there is a more direct commixture between the thalamus and the internal corpus striatum, as well as the external corpus striatum.

The origin of a large portion of the cerebral convolutions, the posterior, middle, and inferior, from the medullary strands connected with the thalami is pretty certain; and correspondingly the reception by the corpora striata of the medullary strands arising from the greater portion of the anterior convolutions—sensation and perception appertaining to the former, voluntary or even unconscious ideo-motor impulse arising in the latter. It may be seen by ablation of the convolutions bordering the island of Reil that the extent of the latter corresponds with the extent of the corpora striata and thalami, and that the lenticular portion of the corpus is in apposition behind with the thalamus. But many anatomists, as Kölliker, deny the uninterrupted descent of locomotive medullary fibres of the brain through the corpora striata.

Dr Broadbent makes the convolutions which are connected with the crus to have each one, both motor and sensory fibres, distributed together through the internal capsule so called; and besides each one, callosal fibres.

Meynert is of opinion that the corpus striatum, and also the thalamus, are connected with almost all parts of the hemisphere—the former, however, more especially with the anterior lobes, and the latter with the posterior; and therefore that every convolution is not destitute of both motory and sensory fibres. That there are direct fibres from the medulla spinalis to the convolutions is inferred by Huguenin and others, and it has been seen that degenerations of the cord have had corresponding lesions in the convolutions, but not in the just mentioned ganglia. These lesions, concomitant with paralysis, or congenital deficiencies, or defects of development, such as the original want of a hand or defect in an organ of sense, often furnish additional corroboration of the doctrine of cerebral localisation.

It must be added, moreover, that Dr Broadbent, whilst he says there is an uninterrupted passage of the crus into the convolutions in part, makes the corpora striata most intimately connected with the crus, the thalami, on the contrary, with the convolutions; and observes "anatomical structure does not lead us to expect that there will be a distinct sensory and motor region of convolutions."

Dr Broadbent further denies that all convolutions are connected with either the corpora striata or thalami. For instance, the lateral convolutions situated between the longitudinal or marginal, and those surrounding the island, though upon transverse sections of the brain these appear to give off fibres descending to the crus. It is evident, however, that the convolutions are bound together by longitudinal commissural bands. The convolutions on the internal surface within the longitudinal fissure are evidently so connected, as shown by their crested disposition, and so well figured by Foville. The commissural fibres, including the important series of arcuate fibres connecting the gyri together, are perhaps as extensive as those of a radiate disposition.

But, contrary to what Foville supposes, the corpus callosum is not a portion of the divergent crura bending inwards and forming a kind of enclosure to the ventricles, nor, as Swan teaches, a commissure of the inner margin of the hemispheres. It is seen upon sections of the hemispheres to arise from almost all parts of them, the anterior commissure helping, however, to connect the temporal lobes and corpora striata in a transverse way; whilst the fornix, with its accessory bandelettes, unites the hippocampi and temporal tuberosities in a longitudinal manner to the grey matter within the ventricles, and at the base of the brain about the optic chiasma—in fact, it seems to belong to the system of the corpus callosum, and to the intercerebral septum.

Perhaps this general review of the subject may point out to some extent what is the truth in this difficult piece of anatomy and physiology; but there are many points which await further elucidation, even the course and connection of the principal cerebral strands, which must be all-important factors as regards function.

The motor portion of the cerebrum, as determined by experiments, corresponds pretty well with the parts which are shown by the anatomy as probably connected with the crusta, and to have that function. In this front part of the brain, however, are parts not having a motor function. Nerve roots from the first nerve join the anterior commissure, and so go to the temporal lobe, and thence to that more posterior part of the brain which, with its centre (the thalamus), appears to appertain to sensation. These last ganglia also receive other fibres from the frontal lobe and head of the corpora striata, as already said.

Of course, as might be expected, numerous objections have been made to the doctrine of localisation—as unavoidable diffusion of the currents, the excitability of the action *solely* by the electrical irritation, and on the supposition insisted on by Brown-Séquard, that the brain acts *en masse*, and that its motor power is not differentiated in any particular localities of it. This physiologist also calls in inhibitory action to account for the phenomena, of which last theory Dr Dodds observes that, while it "has little to support it in fact, its adoption lands us in hopeless difficulties." Schiff and other physiologists, totally contrary to Ferrier, believe all the convolutions to be sensory, and the contractions to take place from the transference of impulse to

the lower ganglia. The latter may be the case sometimes, and the convolutions irritated not the *pons et origo* of the motion, influenced by the will in the normal state. They may be in some cases sensori-motor, or connected with more distant convolutions, the latter receiving impressions from the organs of sense. Extirpation, &c. of convolutions strengthens the doctrine of localisation, though the loss of motion is liable to be recovered from, especially in the lower animals, and in this case it appears to us that Ferrier's view is very probable—that the actions regained are of a different kind, more automatic, and the result of the action of lower centres. The phenomena of aphasia, according to Broca's view, remarkably confirm the doctrine of localisation; and, moreover, show that the left hemisphere takes the lead, almost without exception, in initiating the movements necessary to speech. Therefore, it happens that we need only walk the wards of an hospital or asylum to see the very general association of aphasia with right hemiplegia.

Dr D. J. Cunningham records a case in which a large subarachnoid cyst "corresponded to the position of the following convolutions:—(1) The ascending parietal; (2) the supramarginal, or the convolution of the parietal eminence; (3) the angular; (4) the posterior portion of the superior temporo-sphenoidal convolution." The patient was peculiarly affected with a general hypertrophy, but "he had no symptom whatever of paralysis or paresis."—*Journ. of Anat. and Phys.*, 1879.

Dr Carmichael, in the same journal for 1880, relates two cases of lesion of the temporo-sphenoidal lobe without any indications of loss of special sense.

I should expect that in cases where the left external frontal lobule is solely diseased that there will be aphasia and right hemiplegia during life; but they also undoubtedly occur with extensive disease of the left island of Reil, the left hemisphere, &c., while the frontal lobules remain healthy or nearly so; but this from faculties being injured which are requisite in speech.

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INDEX.

A.

B.

C.

D.

E.

F.

R.

S.

T.

U.

V.

W.

Y.

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Fig. 1

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Fig. 2

a

d

b

c

Fig. 6.

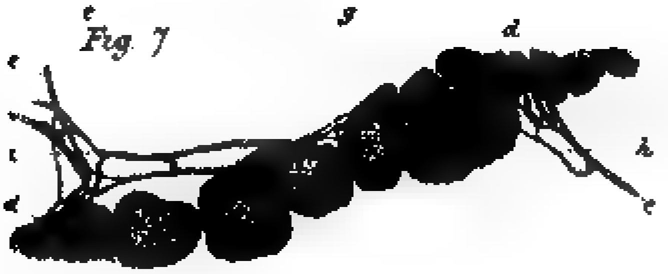

Fig. 7

Fig 8

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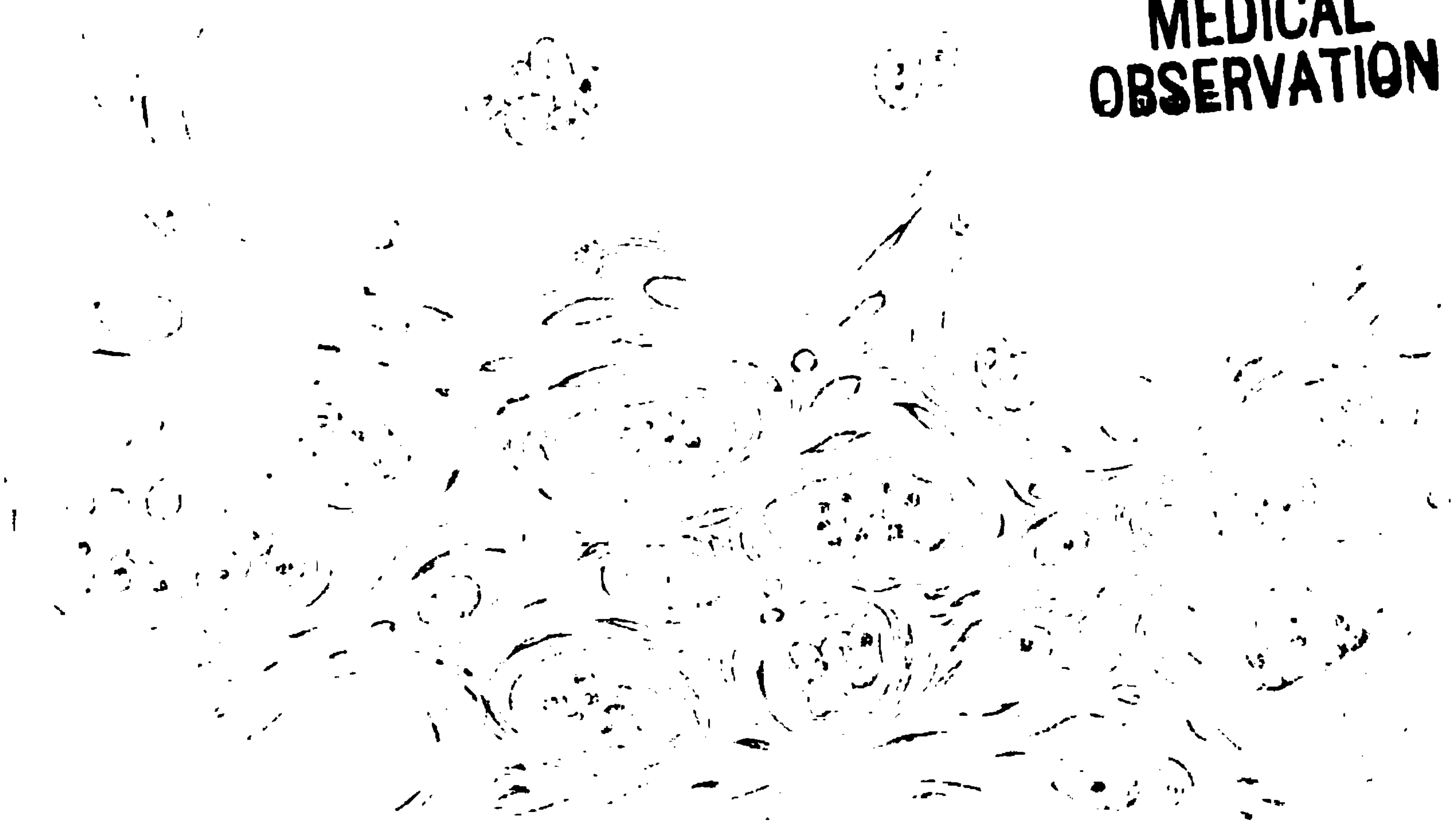

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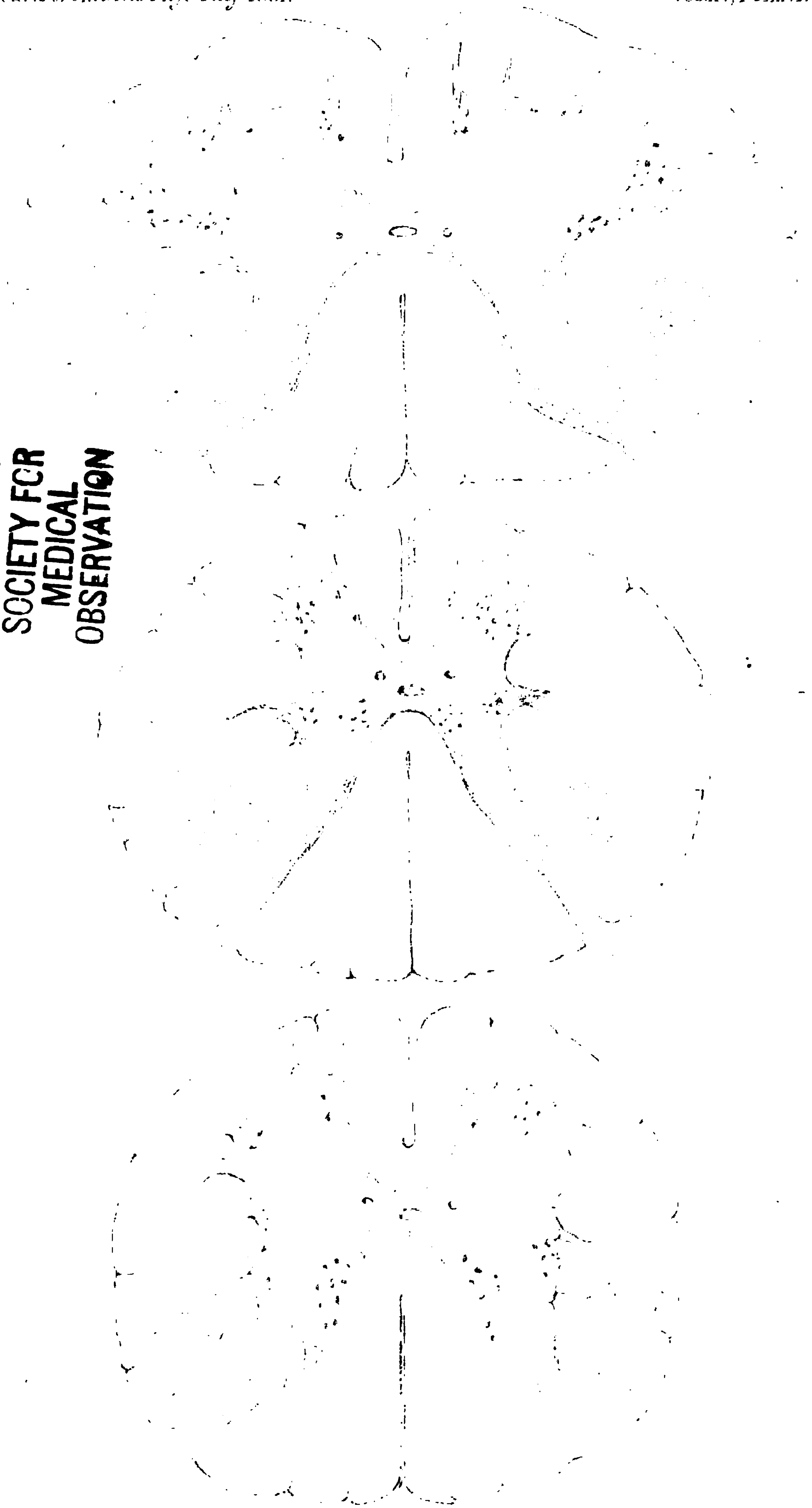

Journ. of Anat. & Phys. July 1881.

1031